An Aviation Weather Preflight Decision Support Tool to Improve Ga Pilots Preflight and Inflight Performance

Jayde M. King

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AN AVIATION WEATHER PREFLIGHT DECISION SUPPORT TOOL
TO IMPROVE GA PILOT’S PREFLIGHT AND INFLIGHT PERFORMANCE

________________________________________

by

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B.S., Air Traffic Management, Embry-Riddle Aeronautical University, 2014
M.S., Human Factors, Embry-Riddle Aeronautical University, 2016

A dissertation submitted to the Department of Human Factors and Behavioral Neurobiology in
the College of Arts and Sciences in partial fulfillment of the requirements for the Degree of
Doctor of Philosophy in Human Factors.

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Summer 2020
Signature Page

An Aviation Weather Preflight Decision Support Tool

To Improve Ga Pilots Preflight And Inflight Performance

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This dissertation was prepared under the direction of the candidate’s Dissertation Committee Chair, Dr. Beth Blickensderfer and has been approved by the members of the dissertation committee. It was submitted to the College of Arts and Sciences and was accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Human Factors.

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Abstract

Low hour, inexperienced General Aviation (GA) pilots account for the majority of weather-related incidents, which often result in fatalities. Previous research identifies poor preflight planning practices and a lack of aviation weather knowledge as key contributing factors to the high novice private pilot accident and fatality rate. Research invested into resolving these issues often attempt to introduce new inflight weather technology to assist pilots with weather avoidance. However, these interventions usually result in pilots using the information to strategically navigate closer to degraded weather conditions (Beringer & Ball, 2004; Burgess & Thomas, 2004). Therefore, the purpose of this study was to investigate the effect of a performance support tool for weather preflight (PWDST) on pilots’ preflight performance and inflight performance. Seventy-eight private pilots ($M_{age} = 20.15$, $SD = 2.56$) without instrument ratings were recruited from a Southeastern US university. Forty-one visual flight rule (VFR) private pilots were randomly assigned to the control group (no preflight decision tool) and 37 VFR private pilots were assigned to the experimental group (preflight decision tool). Participants performed a weather preflight and a simulated flight for one VFR into instrument meteorological conditions scenario (i.e., VFR to IMC). Results indicated that participants in the PWDST condition examined significantly more weather products and reported higher weather awareness following the preflight activities than did participants in the control group. Furthermore, results also indicated that participants in the PWDST condition spent significantly less time in IMC than participants in the control condition. Additionally, results revealed that preflight decision-making was predicted by preflight performance and inflight decision-making was predicted by pilots’ awareness of weather inflight.
Findings from this study suggest that preflight weather performance support tools may be able to assist low hour inexperienced with preflight and inflight performance.

*Keywords: Aviation Weather, Performance Support Tools, Automation, Flight decision-making*
Dedication

Dedicated to Vera Martin, Merab Geral Foreman, (1927-2019) my beloved grandmother. I am who I am today because of all the Godly Unconditional Love and Wisdom you have given me. I know I will see you again, until then I will forever cherish you in my heart, I love you.
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First and foremost, I would like to thank God, the Father, Son, and Holy Spirit for blessing me with this opportunity. All things are possible through Him (Matthew 19:26; Philippians 4:13).

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AVIATION WEATHER PREFLIGHT DECISION SUPPORT TOOL
TO IMPROVE GA PILOTS PREFLIGHT AND INFLIGHT PERFORMANCE

General Aviation (GA) incurs the majority of weather-related accidents within civil aviation operations. GA weather-related accidents have a very high fatality rate – a rate has been slowly decreasing over the last 30 years. Further investigation into the accident data reveals, VFR into IMC accidents account for the majority of weather-related fatalities. Previous research also indicates private pilots with low experience and pilots without their instrument rating were the most likely to fly VFR into IMC. Moreover, pilots who fly VFR into IMC tend to have overconfidence in their abilities and a lack of weather knowledge. As a result, research efforts have been invested into solving the general aviation problem, and new technology, training, and understanding has been gathered and assimilated into GA operations. However, the “General Aviation problem”, specifically VFR into IMC, still persists.

Underlying the stagnant GA aviation accident rate may be that pilots have limited understanding of weather products and theory which, in turn, may result in pilots having only rudimentary mental maps of inflight weather. Consequently, a lack of weather situational awareness and inadequate risk assessment may lead to poor decision-making and error. However, if pilots were provided a performance support tool to aid them in the preflight process for weather, pilots’ understanding of weather, weather-related decisions, and inflight weather-related behavior may improve. The purpose of this study is to investigate the effect of a performance support tool for weather preflight on pilots’ preflight performance and inflight performance.
CHAPTER 1

GENERAL AVIATION WEATHER PROBLEM

Over the last 20 years, General Aviation (GA) accidents have accounted for the majority of civil aviation weather-related accidents. Additionally, GA weather accidents have included alarmingly high fatality rates (see figure 1). This issue has been a subject of concern for both the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB). The most dangerous of all GA weather-related accidents are VFR into IMC incidents. Research suggests VFR into IMC occur more frequently amongst low certificate and low hour pilots. This next section will review the GA accident rate and research on possible contributing factors.

GA Weather Accident Rate

The Federal Aviation Administration completed a detailed review of the General Aviation (GA) Weather-related accidents that occurred between 2003 and 2007 (FAA, 2010). The results indicated that general aviation (GA) operations incur the majority of weather-related accidents compared to Part 135 and 121 operations (FAA, 2010). In fact, between 2003 and 2007, 88% of weather-related accidents were defined as GA Operations. Research has also indicated that most weather-related accidents occurred during the day and while performing GA personal operations (FAA, 2010; Fultz & Ashley, 2016; Nall, 2008). Personal Part 91 flight operations accounted for 1,105 of the cumulative 1,532 GA weather-related accidents between 2003 and 2007 (FAA, 2010). In 2007, 39.4% of GA operations were personal flights. However, GA personal flights accounted for 69.1% of GA accidents and 72.9% of GA fatal accidents (Nall, 2008). Additional study results reported that, between 2003 and 2007, 733 Part 91 weather-related accidents resulted in fatalities (FAA, 2010). However, the data indicates the weather-related accident
fatality rate has decreased, from 95 accidents resulting in fatalities in 2003, to 36 weather-related accidents in 2007 (FAA, 2010). Despite the decreasing fatality rate amongst GA weather-related accidents, the severe injury rate has remained stagnant at an average 32.2 % yearly rate (FAA, 2010).

Fultz & Ashley (2016) conducted a review of fatal GA weather accidents by analyzing accidents that occurred between 1982 and 2013. Research revealed between 1982 and 2013, 25% of 58,687 GA accidents identified weather as a primary contributing factor (Fultz & Ashley, 2016). Fortunately, GA weather-related accidents are on a declining trend (FAA, 2010; Fultz & Ashley, 2016; Nall, 2008). In particular, between 1982 and 2013, GA accidents have decreased by 50%, when considering GA accident subcategories, weather-related accidents have declined by 70% (Fultz & Ashley, 2016). However the GA weather-related fatal accidents rate is decreasing at much slower rate than the overall decrease in GA weather-related accidents (Fultz & Ashley, 2016).

![Figure 1. Part 91 Weather-related Accidents by Injury Severity. This graph depicts Injury Severity of General Aviation Weather-related Accidents between 2003 and 2007.](image)
Weather Contributing Factors

Certain hazardous weather phenomena can potentially have a severe, negative impact on flight performance. These include wind, visibility/ceiling, high density altitude, carburetor icing, updraft/downdraft, precipitation, turbulence, structural icing, wind shear, thunderstorm, thermal lift, temperature extremes, and lightning (FAA, 2010). Wind, visibility/ceiling, and high density altitude constitute the top three weather conditions with the most weather-related citations, with wind identified as the most prominent weather contributing factor, with 1,047 weather-related citations (FAA, 2010). In particular, crosswinds, gusts, and tail winds were highlighted as wind phenomena with the most citations (FAA, 2010; Fultz & Ashley, 2016). However, although wind is the most cited condition with 40% wind-related GA accidents, wind resulted in only 13% of GA fatal weather accidents. Capobianco and Lee (2001) claim wind related accidents’ low fatality rate may be a consequence of wind usually affecting flight performance during takeoff and landing procedures (Capobianco & Lee, 2001; Fultz & Ashley, 2016).

In agreement with FAA (2010), Fultz & Ashley (2016) also found temperature, humidity, and pressure as weather phenomena contributing factors. These weather conditions were cited as causal factors for 20% of weather-related accidents and 23% of those accidents resulted in fatalities (Fultz & Ashley, 2016). In particular, carburetor icing and high density altitude were the most cited of the temperature, humidity, and pressure weather condition factors. High density altitude was associated with 42% of weather-related accidents, whereas, Carburetor icing contributed to 34% (Fultz & Ashley, 2016). However, while these subcategories attributed to a remarkable proportion of temperature, humidity, and pressure weather-related accidents, again, fatality rates were relatively low. During the 30-year analysis, carburetor icing was identified as a contributing factor for only 79 fatal weather-related accidents and high density contributing
factor altitude (changes in altitude/pressure, temperature, and humidity that effect engine and aerodynamic performance of the aircraft) for 297 out of 1,268 high density altitude questions (Fultz & Ashley, 2016). Within this category of temperature, humidity, and pressure weather condition factors, structural icing attributed to 50% of weather-related accidents and only 8% of fatal accidents across all categories (Fultz & Ashley, 2016).

Another area of review has been turbulence and convective weather. Fultz & Ashley (2016) cited turbulence and convective weather as a contributing factor for 8% of all weather-related accidents in their period of review. Despite the overall low contributing factor rate, Turbulence and convective weather condition factors have a high fatality rate. In fact, 65% of all the turbulence and convective weather-related accidents resulted in at least one fatality. General turbulence and thunderstorms were associated with the majority of turbulence and convective fatal accidents (Fultz & Ashley, 2016). Capobianco & Lee (2001) theorized the reasoning for the low turbulence and thunderstorm accident rate and high fatality rate may be a result of pilots’ awareness of the negative impact these conditions have on flight performance. Therefore, pilots may tend to avoid thunderstorms (Capobianco & Lee, 2001) but, when these hazards are encountered, these flights often end in fatalities.

Ceiling, visibility, and precipitation is another area of concern. This weather condition category is associated with 27% of weather-related accidents and are affiliated with 71% GA weather-related fatalities (Fultz & Ashley, 2016). Low ceilings/cloud layers and fog were the most cited weather phenomena within the ceiling, visibility, and precipitation contributing factors category. Specifically, low ceilings/cloud layers accounted for 57% of ceiling, visibility, and precipitation weather-related fatal accidents, while, fog contributed to 40% of ceiling, visibility, and precipitation weather-related accidents and fatal accidents.
Weather conditions associated with the ceiling, visibility, and precipitation condition category are weather phenomena that largely constitute instrument meteorological conditions (IMC). The FAA General Operating Flight rules (FAA 14 CFR) define IMC as weather conditions below the weather minimums required for flight within visual flight rules. The CFR requires pilots to fly in accordance with Instrument Flight Rules (IFR) when flying in IMC. The majority of weather-related accidents described in this ceiling, visibility, and precipitation weather condition category were Visual Flight Rules flight operations in IMC. Capobianco & Lee (2001) also claim that VFR into IMC was often associated with pilot error, pilots flying close to VFR minimums and becoming immersed in IMC.

It is also interesting to consider how weather accident rates have changed over time. Although some reports indicate decreases in weather accidents, others show increases or no-change. This is particularly true regarding fatal accidents. Overall, results indicate the proportion of wind related accidents have increased from 44% of all GA weather-related accidents in 1982 to 60% in 2013 (Fultz & Ashley, 2016). In contrast, turbulence related accidents have shown small decreases in accident rate during the study time period. Similarly, ceiling, visibility, and precipitation GA weather-related accidents have decreased from 30% to 15% over the course of the observed time period (Fultz & Ashley, 2016). However, despite the improvement with a decrease in percentage of ceiling, visibility, and precipitation related accidents, this weather condition category still accounted for 60% of GA weather-related fatalities during the study period. In fact, Fultz & Ashley (2016) argue that the decrease in GA weather-related accidents may be due to a general decrease in GA operations as a whole, rather than, improved pilot understanding of weather and hazardous weather.
VFR to IMC

Thus, VFR into IMC is markedly one of the most dangerous of all GA weather-related accidents (Capobianco & Lee, 2001; Fultz & Ashley, 2016). As a result, research has been aimed toward determining the primary contributing factors for GA weather-related accidents, specifically, VFR into IMC (Goh & Wiegmann, 2001). Previous research suggests inadequate preflight planning, poor decision-making, poor situational awareness, inadequate risk assessment, and technology may play a key role in pilots flying VFR unintentionally into IMC (National Transportation Safety Board, 2005). Because of the danger inherent to VFR to IMC, the current research will focus on that weather phenomenon.

Pilot Qualifications

Research has shown that private pilots have incurred the majority of fatal accidents (Nall, 2008). Specifically, 773 GA weather-related accidents that occurred between 2003 and 2007 featured Private Pilot as the Pilot in Command (PIC), while 460 PIC held a Commercial certificate, and 179 held an Airline Transport Pilot certificate (ATP) (FAA, 2010). Goh & Wiegmann (2001) conducted a specific analysis on VFR into IMC accidents from 1990 until 1997. Their results were similar to the results found in Fultz & Ashley (2016), the majority of pilots who encountered adverse weather inadvertently held a pilot certificate or less without an instrument rating. Additionally, Goh & Wiegmann (2001) found that the majority of the VFR into IMC accidents were encountered inadvertently. They suggest these pilots may be less experienced interpreting weather, resulting in poor situation evaluation and poor decision-making.

In summary, non-fatal GA weather-related accident rate seems to be declining. However, the GA weather-related fatal accident rate is slowly decreasing (Capobianco & Lee, 2001; FAA,
Further investigation has highlighted VFR into IMC, specifically ceiling and visibility, as one of the most dangerous and frequently occurring GA weather-related fatal accidents. (Capobianco & Lee, 2001; Fultz & Ashley, 2016). The pilots who encounter a VFR to IMC situation are usually Private pilots without instrument certification.

To comprehensively address the issue of VFR into IMC accidents, it is imperative for researchers to thoroughly understand the causal factors behind VFR into IMC accidents. The next section will first describe weather sources and products available for pilots to use to avoid VFR into IMC.

Weather Sources and Products

Weather sources can have a prominent effect on a pilots’ preflight planning and inflight abilities (Parson et al., 2005). Therefore, it is important for pilots to select proper weather sources. There are three primary FAA approved sources for preflight weather information: Aviation Weather Center, and Leidos 1-800wxbrief. These sources offer a variety of weather products used to report weather phenomena. As shown in Table 1, there are three categories of weather products, Analysis, Forecasts, and Observations (FAA, 2016).
### Table 1.

**Weather Products Descriptions**

<table>
<thead>
<tr>
<th>Category</th>
<th>Product Name</th>
<th>Presentation</th>
<th>Description</th>
<th>Inflight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation</td>
<td>Metar</td>
<td>Graphical and Textual</td>
<td>This product reports current weather at an airport at the time of observation, including: Wind, Visibility, Runway Visual Range (RVR), Present Weather Phenomena, Sky Conditions, Temperature, Dewpoint, and Altimeter Setting.</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Pilot Weather Report</td>
<td>Graphical and Textual</td>
<td>This product is a self reporting summary of weather phenomena in an area.</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Radar</td>
<td>Graphical</td>
<td>This product reports intensity of precipitation occurring in a certain area.</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Satellite</td>
<td>Graphical</td>
<td>Satellite products report temperature and sunlight reflected from the earth's surface and clouds. With this information, pilots can infer cloud position and height.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Surface Analysis</td>
<td>Graphical</td>
<td>This weather product reports pressure systems and front types.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Ceiling and Visibility Analysis</td>
<td>Graphical</td>
<td>This weather product reports real-time weather conditions such as, Flight Category, Ceiling, and Visibility.</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Sigmet (convective and non convective)</td>
<td>Graphical</td>
<td>This weather product reports Severe Turbulence, Icing, Widespread Thunderstorms, Dust storms, and Volcanic Ash.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Graphical Airmet</td>
<td>Graphical and Textual</td>
<td>This product reports forecasted weather conditions, including: IFR, Ceiling, Visibility, Icing, Freezing Level, and Turbulence at specific times.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Terminal Area Forecast</td>
<td>Textual</td>
<td>This product is a concise forecast of weather within 5 statute miles of airport for a specific time.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Winds Aloft</td>
<td>Textual</td>
<td>This product provides a forecast of temperature, wind direction, and speed at certain times.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Freezing Level Chart</td>
<td>Graphical</td>
<td>Reports lowest freezing level heights</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Surface Prognostic chart</td>
<td>Graphical</td>
<td>This product provides a forecast of precipitation, pressure systems, and fronts.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Low level Significant Weather Chart</td>
<td>Graphical</td>
<td>This product reports flight categories, freezing levels, and turbulence.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>CIP/FIP</td>
<td>Graphical</td>
<td>This forecast reports icing location, severity, and probability.</td>
<td>No</td>
</tr>
</tbody>
</table>
First, analysis products are augmented representations of observed weather information or presentation of an atmospheric phenomena (temperature and ceiling height). Most analyses present automated information (FAA, 2016), which is information that has been gathered and synthesized using automation with no human meteorologist personnel involved in the process. The surface analysis chart and the Ceiling and Visibility Analysis (CVA) are two analysis products (see Table 1). The surface analysis is a graphical product that displays fronts and surface pressure information, while CVA is a graphical product that reports ceiling and visibility information as well as flight categories. Analysis products are crucial for preflight weather planning; they provide the user with current regional and national weather conditions. This information helps pilots understand current weather conditions.

Observation products present raw information obtained from weather sensors, examples of observation information include, METAR and Radar. METAR reports weather information at a specific airport and Radar reports precipitation activity (FAA, 2016). Both Observation and analysis products are crucial for preflight weather planning; they provide the user with current specific, regional, and national weather conditions (see Table 1).

Forecasts are predictions of how weather phenomena will develop. Examples include Terminal Aerodrome Forecasts (TAF) and significant meteorological information (SIGMET) charts. TAFs provide a summary of forecasted weather conditions for a specific area (FAA, 2016). SIGMETs are graphical products that provide forecasted hazardous weather information (FAA, 2016). Forecasted products help pilots perceive weather trends and plan for developing weather conditions along their route (see Table 1).

However, even with all of the weather products available, pilots are still having difficulty with preflight and inflight weather avoidance (Fultz & Ashley, 2016). This could be due to the
cognitive complexities associated with understanding aviation weather and performing preflight and inflight cognitive tasks. However, before describing the preflight and inflight tasks, it is important to review the human information processing model.

**Human Information Processing**

Cognitive Tasks are assessed through investigating how operators process information and select and execute actions. As shown in Figure 2, one of the most researched models for understanding human cognitive process is the Human Information Processing Model (Wickens, Gordon, Liu, & Lee, 1998).

![Human Information Processing Model](image)

*Figure 2. Human Information Processing Model*

The human information processing model is organized into three main components, encoding sensory information, central processing of information, and response selection. During the encoding sensory stage, stimuli input is sensed by the operator through visual, auditory, haptic, or olfactory sensor receptors (see Figure 2). Once the information is registered, the information is perceived, in other words, the received raw sensation is given meaning. For example, when pilots
receive taxi instructions from ATC, this information is sensed by the operators’ ears as sound waves and then perceived by the brain as taxi instructions.

Then this information is stored in the person’s short term memory. Usually, unless rehearsed, short term memory can only hold seven to nine chunks of information before information is lost. However, if this information is processed and stored in long term memory the information will be accessible much longer and the total long term memory capacity is vast. The brain uses information stored in short/working memory and long term memory to select and execute responses. For example, in the case of the previous ATC taxi scenario, once the taxi instructions are stored in working memory, the brain recalls information from long term memory such as a mental model of the airport diagram and taxiways. The recalled information assists pilots when executing directions and deciding whether to turn right or left. Then, once the decision is made, the operator relies on information from long term memory on piloting and taxi skills to help execute the action. Using the information processing model, researchers can complete a task analysis and identify possible limitations, and hazards for users and in turn, develop solutions.

This next section reviews the weather preflight planning process to identify components that may cause limitations and errors.

**Preflight Planning**

Preflight weather planning is crucial to safe GA operations. Although pilots access weather while in-flight, most of weather product interpretation and planning occurs during the preflight phase. During preflight planning, pilots use aviation weather knowledge and skills to interpret weather information concerning their flight route. The FAA divides the preflight weather planning process into three main components: Perceive, Process, Perform (Parson et al., 2005).
Beginning with the “perceiving” phase, pilots are gathering information to conceptualize meteorological conditions along their route (Parson et al., 2005). Information acquisition is a crucial component of the preflight process. If incomplete or in error, pilots may not receive vital information (see Table 2). When completing the preflight process, pilots first identify their route and landmarks on their aeronautical sectional chart (Parson et al., 2005). Next, pilots review the weather along their route by accessing various weather products (Parson et al., 2005). This is described as the information acquisition step. However, there are numerous factors that can hinder this process.

When gathering information, it is imperative pilots select the appropriate weather sources. Although there are various weather sources available for pilots, pilots should consider the various weather source vendors (e.g. Aviation Weather Center (AWC), 1-800 Weather Brief), how the information is produced (Lanicci et al., 2012), and limiting factors (Blickensderfer et al., 2015). All these factors such can dramatically impact the quality of weather information provided and stored in the working memory.

In the gathering information and perceiving stage, a number of challenges may arise. First, pilots may have difficulty accessing certain products due to the usability of the weather source (Latorella & Chamberlain, 2002; Defilippis et al., 2018).

Table 2.

**Preflight Task Analysis**

<table>
<thead>
<tr>
<th>Steps</th>
<th>Tasks</th>
<th>Tools</th>
<th>Knowledge</th>
<th>Skills</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceive</td>
<td>Decide which product to access</td>
<td>N/A</td>
<td>Knowledge of product report information</td>
<td>N/A</td>
<td>Failure to access essential products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Knowledge of product limitations</td>
<td></td>
<td>Failure to select correct weather products for retrieving information on various weather phenomena</td>
</tr>
<tr>
<td>Process</td>
<td>Interpret the accessed product</td>
<td>The accessed weather product</td>
<td>N/A</td>
<td>Failure to accurately interpret product information</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------</td>
<td>-------------------------------</td>
<td>-----</td>
<td>-----------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Find desired product</td>
<td>Weather sources: AWC, Duats, 18000 wx brief, Foreflight</td>
<td>Knowledge of product issuance times</td>
<td>Knowledge of product limitations</td>
<td>Ability to navigate the AWC website</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Knowledge of product issuance times</td>
<td>Knowledge of product limitations</td>
<td>Failure to collect all appropriate products by excluding region information</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Knowledge of interpretation criteria specific to each product</td>
<td>Knowledge of how to interpret each product</td>
<td>Failure to collect time valid products</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Knowledge of product legend</td>
<td>Knowledge of aviation weather principles related to reported weather phenomena</td>
<td>Failure to collect correct weather information</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Knowledge of Product limitations</td>
<td>Knowledge of Product limitations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For example, if a pilot wants to access infrared satellite images using AWC, the pilot may not be able to find the weather product due to poor website design. On the AWC website, to access the satellite products, pilots have to discern whether satellite images are categorized as a forecast, observation, or an advisory product. After selecting the satellite image type option, users then
need to know which geographical region they need a report for and which type of satellite image would provide them with the information needed. This process can be very cognitively taxing and complicated for a novice pilot to navigate on their own, pilots may not be able to recall this information easily from their long term memory (see Table 2).

Additionally, pilots may be unfamiliar with product limitations and may access inappropriate products for information regarding certain weather phenomena (Lanicci et al., 2012). For example, if a pilot wants to evaluate cloud coverage along their flight route, and they access radar believing they will receive information on cloud location and movement, the information they receive would be misleading. For example, radar only reports precipitation, not cloud information. Also, since the product is new to the user, the pilot will have to rely more on their working memory.

Another challenge is simply remembering to access all applicable weather products that would inform them of the conditions for their flight. Checking multiple products is necessary to get a robust understanding of the weather (Vincent et al., 2013). Depending on the weather source accessed, while the weather products are available, no guide exists for the pilots prompting them on what products to examine for their preflight plan. For less experienced pilots, this may result in incomplete review of products as pilots may simply forget to access certain weather products with valuable information. This could be a result of too much information being stored in the working memory, which can lead to mistakes and erroneous performance.

After accessing the weather products/information, pilots need to analyze the information received, this is referred to as the “process stage” (Parson et al., 2005). During this stage, aviation weather principles are used to interpret weather products (e.g. Table 2). Again, product usability can serve as a barrier between pilots and needed weather information (Latorella &
Chamberlain, 2002). For instance, certain weather products do not feature legends or their legends do not feature all the symbols present on the weather product (e.g. Aviation Forecast). With the multitude of weather products available, it is unlikely that pilots have what each symbol and abbreviation represents for every weather product in their long term memory. Additionally, some weather products may display a legend; however, the legend itself may be unclear regarding the weather phenomena being reported in the product. For example, consider infrared satellite imagery, the legend presents the various colors used in the product and informs the user the different colors are associated with different temperatures (FAA, 2016). However, the product does not show any information informing the user that the light colors and cooler temperature are used to imply higher altitude clouds, whereas the darker colors imply lower altitudes. The legend assumes that the user (in this case pilots) possess a high level of knowledge of these concepts. Unfortunately, assumptions such as this can make product interpretation a challenging task for novice pilots.

The next step in the preflight planning process, “Perform” requires pilots to make decisions based on their evaluation of the weather reports (Parson et al., 2005). However, a lack of capability to interpret weather products combined with a lack aviation weather knowledge could limit the effectiveness of pilots’ weather-related decision-making (Blickensderfer et al., 2015). It is possible that, due to a poor knowledge of aviation weather principles, pilots may be incapable of linking weather reports to certain weather phenomena. For example, the Surface analysis chart displays a legend clearly decoding all the symbols used on the product. However, If the user does not understand what weather phenomena is associated with high and low pressures, cold/ war fronts, isobars, the product is rendered useless. This is concerning considering that pilots use weather information to decide what aspects of their flight route need alteration due to weather
conditions. Pilots need a grounded understanding of aviation weather fundamentals in their long term memory to understand the weather phenomena being reported and how it will affect their inflight performance. For instance, if weather products report low ceiling and poor visibility, pilots then would have to predict how that weather will develop and when and how it will affect their flight path. Applying weather information to flight operations is crucial for deciding alternate airports and diversion plans in case of emergencies. However, planning for future events can be difficult if pilots have limited aviation weather knowledge. In other words, even if weather products have high degrees of usability (e.g., legends clearly identifying the various symbols and abbreviations etc.), pilots may still have difficulty applying these products due to a lack of understanding of how weather phenomena impact in-flight performance. Without a solid foundation of basic weather principles in the long term memory, and weather condition information gathered in the working memory, users may have limited experience and knowledge to recall to assist with the current challenges of applying gained knowledge from the preflight process to the context of their flight route.

Preflight preparation is crucial to safe flight activity (Parson et al., 2005). However, each step of the preflight process requires pilots to have knowledge of aviation products and weather knowledge. Without an adequate understanding, pilots will be unable to acquire, interpret, and apply weather information. In turn, this could lead to a poorly developed mental model of weather conditions while in flight, which, in turn can have significant negative effects on pilot inflight decisions. While inflight, pilots should refer to preflight weather notes and monitor developing weather by contacting inflight weather sources such as HIWAS, and ASOS. However, without a firm understanding of how weather affects flight performance (long term memory) and a weather plan (working memory), pilots may not be equipped to mitigate
hazardous event while in flight (Lanicci et al., 2012). Therefore, it is imperative to understand and mitigate poor aviation knowledge and skills and to understand products and limitations.

**Decision Making**

Decision-making skills and judgment assessments are essential for weather avoidance and hazardous weather encounter recovery (FAA, 2017). However, humans suffer from various cognitive biases that may hinder logical decision-making (NTSB, 2005). As a result, decision-making errors are prevalent and may be exacerbated depending on information available, environmental factors, and physiological factors (NTSB, 2005).

For example, “pilot continuation” is a decision error where pilots continue flight activity into degrading weather conditions, seemingly ignoring the evidence indicating unsafe flight conditions (NTSB, 2005). This can occur during a VFR into IMC incident, as pilots experience IMC and fail to divert to an alternate airport, change flight route, or return toward a departure airport (NTSB, 2005). It may appear that pilots who find themselves in “VFR into IMC” situations have high risk tolerance, when in actuality there are a variety of factors impacting a pilot’s decision to continue into degrading weather (NTSB, 2005). For instance, it is possible that some pilots continue into IMC due to an inadequate assessment of the current weather situation. Therefore, pilots’ poor judgement may not be a direct effect of the propensity for risk taking; instead, it may be rooted in a misunderstanding of weather and its effects on flight.

“Prospect theory” describes another cognitive bias that can affect weather-related decision-making. Prospect theory explains how framing courses of action as either a “gain” or “loss” can have an effect on participant decision selection (Kahneman & Tversky, 1986). Goh & Wiegmann (2001) explained how prospect theory can affect weather-related decision-making in VFR into IMC incidents. They argued that many pilots associate diverting from their flight route due to
hazardous weather as a loss and that, in turn, this may encourage pilots to continue flight into degrading weather (Goh & Wiegmans, 2001). In contrast, if pilots frame diverting as a gain (i.e., the gain being that they will remain safe and without injury), then pilots may be more likely to divert when facing IMC (Goh & Wiegmans, 2001). O’Hare & Smitheram (1995) also investigated the decision framing effects on decision-making during VFR into IMC accidents. Results indicated that pilots who framed VFR into IMC operations as losses and safe diverting as gains, were less likely to continue flight into degrading weather.

**Experience and Aviation Weather Skill Acquisition.** While decision-making biases may be a contributing factor for VFR into IMC, decision errors may also stem from poor aviation weather knowledge or skill. As aforementioned, most weather accidents occur with less experienced private pilots (FAA, 2010; Fultz & Ashley, 2006). GA weather-related accident data identified low experience, non-instrument rated pilots as the major demographic for VFR into IMC operations (National Transportation Safety Board, 2005) and that operational weather experience is related to weather decision-making abilities and skill acquisition (National Transportation Safety Board, 2005).

Research in skill acquisition and cognitive psychology describes the skill acquisition process as novice operators progress to intermediate and expert proficiency levels (Anderson, 1993; Patel & Groen, 1991: Wiggins & O’Hare, 1995). Research demonstrates that skill acquisition is built through the collection of multiple experiences and cases stored in long term memory (Anderson, 1993). These cases and examples are then recalled and acclimated to assist with the challenge at hand (Dreyfus & Dreyfus, 1986). Operators/pilots at varying levels of expertise and skill acquisition (novices, intermediate, or experts) operate differently. Novices will often function less precisely and skillfully than intermediates, and intermediates less than
experts (Wiggins, Stevens, Howard, Henley, & O’Hare, 2002). Novices’ poor performance is due to the undeveloped knowledge and skills required to complete tasks comprehensively (Patel & Groen, 1991: Wiggins & O’Hare, 1995). Prior research suggests that, as task difficulty increases, the difference between expert and novice information acquisition methods will widen (Woods, 1988). Thus, these differences in skill acquisition may be more prevalent in aviation and preflight planning, due to the task difficulty, high stake risks, and ambiguous weather-related information. It is likely that differences in weather-related knowledge and skills is one reason the private pilots are getting into trouble. Interestingly, however, when investigating differences in pilot expertise, research suggests that intermediate pilots may be more at risk for unsafe flight activity (Wiggins, Stevens, Howard, Henley, & O’Hare, 2002). Intermediate pilots are in a particular position in which they may be more prone to decision-making errors (O’Hare, Wiggins, Batts, Morrison, 1994). Unlike novice pilots, intermediate pilots may not be receiving training. However, unlike experts, intermediate pilots may have not cultivated the necessary skill to make safe decisions (Wiggins et al., 2002). O’Hare, et al., (1994) investigated accident data and revealed, intermediate pilots incurred “goal formation errors” (e.g., Did the pilot choose a goal which was feasible?, Is a missed approach feasible considering the current situation?) more than procedural errors (e.g., Did the pilot execute procedures consistent with the selected strategy?, Did the pilot complete all the procedural steps required to perform a missed approach?) and action errors (e.g., Was the procedure executed as planned?, Was the pilot able to complete this missed approach successfully?). Furthermore, goal formation errors were more prevalent among accidents resulting in serious injuries and fatalities (O’Hare, et al., 1994).

The intermediate level of skill acquisition is analogous to the competent stage (Dreyfus & Dreyfus, 1986), knowledge compilation stage (Anderson, 1983), rule stage (Rasmussen, 1983),
or the associative stage (Fitts & Posner, 1967). All of these stages present an intermediate stage of skill acquisition during which the person is heavily reliant on quantitative processes rather than qualitative task specific processing (Wiggins et al., 2002). Intermediate operators have not fully established efficient expert level qualitative information processing which is necessary to process task related information and implement action effectively (Bell, 1997). This trend may also be prevalent amongst GA pilots. GA weather-related accident data trends suggest GA Private pilots account for the majority of weather-related and VFR into IMC accidents (Goh & Wiegmann, 2002; FAA, 2010; Fultz & Ashley, 2016). This could be due to private pilots’ inability to process weather information and apply it to their flight effectively.

Previous research has investigated expertise with respect to the aviation weather task of Preflight planning. Expertise and aviation weather knowledge can have direct implication on preflight planning for inflight performance. Preflight planning is a complex task as the pilot must integrate aeronautical information and weather information from various sources (Wiggins et al., 2002). Wiggins et al., (2002) employed process tracing to analyze how novice, intermediate and expert pilots accessed information for preflight planning. Process tracing allows researchers to investigate operators’ problem solving based on the order of information acquisition while completing a task (Svenson, 1979). Process tracing can provide insight into how novice, intermediate, and expert pilots access information and make decisions during the preflight process. Wiggins et al., (2002) results indicated that there were differences in information acquisition efficiency between the three groups. Specifically, experts were able to identify necessary information and integrate that information more effectively than intermediate pilots (Wiggins et al., 2002).
These results suggest that intermediate and novice pilots may have difficulty during the preflight process due to their inability to access, interpret and apply weather information. Novice and intermediate pilots may have challenges with the preflight process due to a lack of aviation weather knowledge and poor understanding of product limitations (Blickensderfer et al., 2017). Blickensderfer et al. (2017) and Burian & Jordan (2002) used written examinations to assess pilots’ knowledge and skill regarding aviation weather. The evaluations included weather patterns, weather hazards, weather services, weather regulations, weather product interpretation, and weather-related decision-making. Both studies demonstrated that participants had a low aviation weather knowledge, and in particular that pilots had difficulty answering weather interpretation questions compared to weather principles and decision-making questions. Results also revealed that formal aviation weather training alone increased aviation weather knowledge, but flight experience alone did not necessarily increase weather knowledge.

**Summary.** In summary, research demonstrate most weather accidents occur for private pilots without instrument (FAA, 2010). Additional research shows that expert pilots access weather information differently from novice and intermediate pilots (Wiggins, 2014). Still other research shows that pilots struggle to answer written questions about aviation weather and weather product interpretation (Blickensderfer et. al, 2017). All of this can be leaving novice and intermediate level pilots without the information they need to form adequate situation awareness of the weather for their flights. In turn, poor situational awareness and cue association has been highly linked to low experience and could have implications for GA flight operations.

**Situational Awareness**

Previous research also identifies situational awareness as a contributing factor for the stagnant GA weather-related accident rate and VFR into IMC accidents (National Transportation
Safety Board, 2005). Researchers suggest that pilots encounter VFR into IMC inadvertently and may not be able to recognize the cues of IMC forming in their flight path. Situation assessment research claims this inaccurate assessment of weather development may be related to poor feature association formation in novice pilots (Ellis, 1996). This section briefly reviews Situation Awareness function in GA hazardous weather-related accidents.

SA and experience may be a key factor in the assessment of weather phenomena interpretation and recognition of deteriorating weather (Wiggins, 2014). Long-term memory and cue utilization can help fill gaps of information from inadequate attention and working memory (Wiggins, 2014). Therefore, if pilots lack knowledge of aviation weather principles, it could hinder their abilities to use cue utilization and long-term memory to assess their situation. Research has revealed differences between expert and novice weather phenomena feature recognition (Wiggins & O’Hare, 2003). Which in turn, can determine the quality of weather phenomena assessment while inflight.

When features in the operator’s external environment are related to internal knowledge from past experiences, the resulting construct is a “cue”. Research suggests that these cues are used to help direct human behavior and build mental models (Rosen et al., 2010; Wiggins, 2006, 2012; Wiggins and O’Hare, 2003a). The strength of the relationship between cues can determine whether pilots are able to perform efficient weather phenomena assessment (Wiggins, 2014). These claims are consistent with the Endsley (1995) interpretation of situational awareness and situation assessment, where operators take information from their external environment and make connections with internal knowledge and behavior to predict the future state of the system (Klein, 2008). The initial analysis of the current environment is termed situational assessment, whereas, using that information to predict the future is prospective diagnosis (Uhlarik &
Comerforf, 2002). The operators’ ability to perform accurate situation assessment and prospective diagnosis is contingent on the operator’s development of feature-event relationships (Wiggins, 2014). Research suggests, strong feature-event relationships are built through exposure to the operational environment. Frequent exposure to the system or environment will clarify feature-event associations, enabling the more experienced pilots to respond to events more accurately than those less experienced (Wiggins, 2014). This could provide insight into the high GA Weather accident rate amongst low experienced pilots. Low experienced private pilots, due to a lack of exposure, may not have strong cue association while inflight to assist with situation assessment and weather avoidance.

**Aviation Weather Situation Assessment Measures.** Measuring diagnostic skills and situation assessment is a challenge for general aviation weather research. Although research has been invested into expertise and novice research, most of the expertise classifications have been a priori by hours of experience performing a task. However, this method of assigning expertise is based on length of experience, rather than, of quality of experience (Hoffman et al., 1995; O’Hare et al., 1998). Wiggins (2014) claims diagnostic expertise is determined based on the development of feature event associations and performance, rather than the operators’ amount of flight hours. While it is difficult to determine an accurate response in operational environments, researchers propose measuring diagnostic skills with response latency (Wiggins, 2016). However, response latency may be a difficult measure to use in the context of weather. For instance, if the task requires pilots to predict weather development and avoid deteriorating weather, how can one be sure weather will develop into hazardous conditions without the pilot encountering the weather? Wiggins (2014) employs this approach in most of his studies by investigating information acquisition as a possible measure for diagnostic skills. This approach allows for evaluation of
accuracy, behavior, and cue feature relationship (Wiggins & O’Hare, 1995; Wiggins, 2006, 2012). By capturing the selection and sequence of information acquisition, researchers are able to understand the cues operators perceive as crucial for problem mitigation (Wiggins, 2014). Moreover, operators’ information selection could depict expertise. This is especially informative when assessing pilots’ decision-making in the preflight phase, where weather information is acquired and flight route decisions are determined (Wiggins, 2014). The decisions made in preflight could prevent VFR into IMC, and instead ensure safe flight operations.

Wiggins, Azar, & Loveday, (2012) investigated whether there is an association between weather-related task-specific cue utilization and decision-making. Participants completed a feature association task and a feature discrimination task, response and variance of responses were measured for both tasks (Wiggins et al., 2012). The cue utilization responses were compared to demographics and participants’ performance on a weather preflight scenario (Wiggins et al., 2012). Results from both cue assessments revealed that experts were more definitive in their responses resulting in more variance in their answers compared to non-experts. Preflight and cue assessment results were fairly consistent; however, responses did not correlate with flight hours and certification. Wiggins et al. (2012) claims, these results may be a predictor of pilot preflight performance.

Wiggins, Azar, Hawken, Loveday, & Newman (2014) conducted another study to gain better understanding of experts’ and non-experts cue and feature association when encountering deteriorating weather conditions near their flight destination. Pilots received Expert Intensive Skills Evaluation (EXPERTise) Situational Judgement Test (SJT), based on their composite scores participants were organized into two categories. The assessment consisted of a feature identification task, a feature association task, and a transition task (Wiggins et al., 2014).
being sorted into the two groups participants were required to review flight plan and weather, to determine whether to undertake the simulated flight scenario (Wiggins et al., 2014). Then a subset of the two groups were chosen to fly the in flight simulation. Weather in the scenario was VR into IMC, the weather deteriorated close to the flight destination (Wiggins et al., 2014). Results indicated participants in the less experienced cue utilization group decided not to embark on the flight due to a lack of information. Where, the more experienced cue utilization group were more likely to embark on the flight and fly into degrading weather conditions. However, once again these results did not correlate with flight hours, risk perceptions or pilot certification (Wiggins et al., 2014).

The lack of correlation between flight experience/pilot certification and aviation weather cue utilization and decision-making could be related to the poor measures for aviation weather situation and cue association assessment or it could support the suggestion that the traditional means of aviation experience (flight hours and pilot certification) do not predict aviation weather knowledge and skills. Instead maybe weather training or other factors should be considered when predicting aviation weather knowledge and skills.
**Aviation Weather Cue-Based Training.** Wiggins & O'Hare (2003) developed “weather-wise”, a cue-based training program to help pilots form stronger feature associations. Chansik (2011) conducted a study to investigate how weather recognition training effects GA pilots’ situation assessment in deteriorating weather. After taking the course, pilots were assessed on their ability to perceive changing weather conditions, risk perception, risk tolerance, and decision accuracy (Chansik, 2011). Results indicated, the group that received the weather wise training displayed significantly higher ceiling estimation and decision accuracy performance, however there was no significant difference between groups on risk tolerance, risk assessment and decision confidence (Chansik, 2011). These results could support the notion weather training is helpful to improve pilots’ aviation weather knowledge.

**Summary.** In summary, research has identified SA as a crucial component for the GA weather-related accidents. Specifically, previous studies have evaluated pilots SA during pre-flight and simulated inflight within developing weather (Chansik, 2011; Wiggins et al., 2014; Wiggins et al., 2012). Despite the various attempts to train and measure experience and weather SA, the new proposed measurements have yet to correlate with traditional expertise measurements (i.e. flight hours, pilot certification, etc.). This could support the claim that traditional pilot expertise measures may be accurate for flight performance; however, they may not be indicative of pilots’ aviation weather knowledge and weather SA. Additionally, with mostly a priori weather SA assessments, there are limited measures available to validate new aviation weather SA measures. Furthermore, the limited measures available for both aviation weather knowledge and situation assessment provide is little explanation as to why low experienced pilots account for the majority of aviation weather-related accidents. However, risk has been identified as a contributing factor to GA weather-related accidents. Therefore, it is
imperative to investigate how risk and poor pilot judgement relate to GA low experience pilots and weather-related accidents.

**Risk Assessment**

Risk assessment has been linked to poor pilot judgment of GA scenarios, which may lead to possible weather avoidance errors (O’Hare 1990). Most of the aviation risk related literature address operators’ behavior in risky situations by considering risk from two different, yet associated concepts: perception and tolerance.

**Risk perception and Risk Tolerance.** Risk perception is defined as the ability to identify and evaluate risk associated with hazardous events (Hunter, 2002). Brown & Groeger (1988) theorize that risk perception is comprised of information gathered from the environmental hazards and the operator’s abilities. For example, less experienced operators may not have the ability to efficiently assess hazards and risks. In other words, if pilots lack a developed understanding of how weather develops and effects flight, it may hinder accurate and effective risk perception (Hunter, 2002). Consider VFR into IMC. Less experienced pilots may not pick up on cues in the environment that indicate hazardous weather is developing. To effectively assess risks, operators need to be able to appropriately perceive external situations (Hunter, 2002). Improper evaluation of the weather situation may result in an underrated understanding of the hazards involved in the situation and may result in an over-estimated confidence in individual skills to navigate the situation (Hunter, 2002). Overestimation of personal pilot skills has been cited as a contributor to VFR into IMC accidents, but again, this may be a result of a misperception of the risks associated with aviation weather.

Risk tolerance is more difficult to define, as risk tolerance is reliant on personal characteristics and internal factors (Hunter, 2002). Previous research suggests that risk tolerance
can be mediated by the value affiliated with the goal or task, and risk tolerance may change depending on the situation. For instance, the same individual may have low risk tolerance when taking a trip to the grocery store to pick up an item that they could buy another time and the same person may exhibit a high risk tolerance when evacuating due to an impending severe storm. (Hunter, 2002).

With respect to aviation weather, if pilots misinterpret cues, they may not have accurate risk perception. As a result, a lack of aviation weather knowledge, and poor cue feature association may have an influence on pilots’ risk tolerance. Knecht (2008) claims that experience in certain weather phenomena can influence subsequent pilot decision-making and how they use weather-related information. Operators need to be able to identify weather risks and mitigate the situation (Ferraro, Vandyke, Zander, Anderson, & Kuehlen, 2015).

Hunter (2002) investigated whether risk perception and risk tolerance have separate effects on pilot decision-making. Results indicated that there was a negative relationship between pilot risk perception and risk tolerance (i.e., as risk perception increased, risk tolerance decreased). Therefore, pilots who are not sensitive perceivers of risk in hazardous weather, may also have a tendency to take higher risks in other tasks and situations. In congruence with the principles of the zero risk theory, a higher level of risk was associated with a lower perception of risk. However, student pilots also displayed low level of perceived risk. Hunter (2002) explains student pilots may be too novice to accurately assess risk. Previous research suggests that risk perception matures as the operator gains more experience with their task and their environment (Jensen et al.’s 1997; Wiggins and O’Hare’s 2003). Risk has previously been measured through pilots rating risks in simulated flight scenarios (e.g., Hunter, 2002; O’Hare, 1990). This measure, however, did not account for the accuracy of the risk appraisal. Researchers claim it is difficult
to determine the correct level of risk perception, as often there is no definite “correct” perception of risk (Weiss & Shanteau, 2003). Different pilots apply different factors to decision-making, this can make the decision-making process very dynamic and difficult to predict (Knecht, Harris, & Shappell, 2004).

Finally, Ferraro, Vandyke, Zander, Anderson, & Kuehlen (2015) compared risk assessment ratings of weather by non-aviation experienced students to aviation experienced students. Results revealed that aviation experienced participants rated weather-related scenarios as riskier than non-aviation experienced participants. However, the pilots’ overall risk perception declined with more flight and simulated flight hours, which may suggest that risk perception should be continuously trained (Ferraro et al., 2015).

**Summary.** In summary, previous research has associated poor risk perception and risk tolerance with low experience pilots. If low experienced pilots have poor knowledge of aviation principles it could hinder their ability to understand the risks associated with weather conditions and their effect on aircraft performance. When pilots enter weather conditions, unaware of its effect on flight, pilots may encounter hazardous weather phenomena.

**Weather Technology**

Weather technology and weather products have become a crucial component of the preflight process. During the late 1990’s and early 2000’s, researchers and engineers introduced a variety of graphical weather products in an attempt to give GA pilots access to more usable weather information (Tallotta et al., 1997). Early research results revealed that pilots with graphical weather information systems (GWIS) had better awareness of weather and less dependence on ground weather professionals, but this was accompanied with higher workload (Yucknovicz et al., 2000). Although the introduction of GWIS as well as radar (e.g., NEXRAD) have the ability
to increase pilots’ awareness and decrease weather information retrieval time, researchers have found repeatedly that pilots may use these devices to actually fly closer to hazardous weather conditions and maneuver around them (Latorella & Chamberlain, 2002; Yuchnovicz et al., 2001; Berringer and Ball, 2004). Latorella & Chamberlain (2004) claim the NEXRAD display of storm cell location, intensity, and position in relation to the aircraft, made it easier for pilots to use the interface more strategically (Latorella & Chamberlain, 2004).

Previous studies investigated how much degraded radar resolution affects pilots’ weather interpretation and decision-making (Latorella & Chamberlain, 2004). Results indicated that higher resolution NEXRAD radar images encouraged pilots to use technology tactically to maneuver through hazardous weather. Latorella & Chamberlain (2004; 2002) called for more research with high resolution radar images and IMC conditions to further explore this notion. Beringer and Ball (2004) also investigated the ranges of NEXRAD spatial resolution. Results were similar to Latorella & Chamberlain (2002) in that pilots who accessed higher resolution used the information to maneuver around and dodge hazardous weather (Beringer and Ball, 2004). In fact, the majority of pilots in the study violated the 20 statute mile distance from storms (Federal Aviation Administration [FAA] & National Oceanic and Atmospheric Administration [NOAA], 1983). This is similar to the findings in Wu, Gooding, Shelley, Duong, and Johnson (2012), where under similar conditions, pilots flew within the FAA suggested 20 statute mile distance of convective weather, and disregarded hazardous weather avoidance practices. Burgess & Thomas (2004) assessed the effect of new, innovative cockpit displays on pilot decision-making and weather avoidance. This study compared a novice display featuring NEXRAD image loop to a National Convective Weather Forecast. Results indicated no
significant difference between groups’ weather avoidance performance regardless of condition (Burgess & Thomas, 2004).

**Portable Weather Technology.** Recently the GA community has been investing in lower cost portable devices that map weather information along flight routes to improve pilots weather SA and weather avoidance. The majority of the portable weather technology (e.g. Foreflight) that are currently available are weather apps on tablets, smart phones, or smart watches. Industry is introducing more aviation weather apps each year (Dutcher & Doiron, 2008). However, researchers have identified various human factors issues associated with portable weather devices. For example, Schaub, Karl, and Weber (2010) found a lack of standardized training, device size, warning messages, and navigation all pose limitations to pilots’ ability to use portable weather devices.

Additionally, Ahlstrom et al.(2016) investigated the effect of portable weather devices on GA pilot behaviors, GA pilot weather situational awareness, and weather avoidance. Results, indicated the portable device increased pilots’ weather situation awareness. Also, the introduction of the portable device did not degrade pilot performance (Ahlstrom et al., 2016). However, pilots still operated too close to degraded weather. As with other weather products and technology, any possible beneficial effects of weather apps may be limited by pilots lack of weather knowledge and device training (Ahlstrom et al., 2016). Ahlstrom et al.(2016) advocated for more research on aviation weather information interpretation training (Ahlstrom et al., 2016).

**Summary.** Recently, research has attempted to improve preflight and inflight performance through new weather technology with improved usability. However, despite the advances in technology and weather product display, pilots often utilize the weather information to fly closer to deteriorating weather. GWIS and portable weather technology both have benefits and
limitations for presenting weather along pilots’ flight route. Latorella & Chamberlain (2002) claim that GWIS should assist pilots with realizing how weather conditions relate to the overall flight mission, this includes assisting pilots in predicting how weather will develop in the future, identifying when weather is hazardous, and suggesting actions (Latorella & Chamberlain, 2002). However, previous research confirms that GWIS and portable weather applications do not assist pilots in safely navigating around hazardous weather. In fact, multiple studies claim GWIS may promote tactical maneuvers too close to degrading weather. Weather technology does not seem to mitigate pilots’ decision-making, situation assessment, and product interpretation errors. Furthermore, low experienced pilots poor preflight and inflight behavior does not seem to be mitigated through better weather technology. New technology may be unable to improve pilots understanding of weather and preflight performance due to pilot’s lack of ability to interpret weather products and understand basic weather theory.

As aforementioned, product interpretation can be difficult for many reasons, pilots would need to understand product symbols, limitations, and application. Additionally, with the various products available, aviation weather principles may be very difficult for pilots to comprehend and apply. However, if pilots had access to a preflight planning guide to assist with product interpretation, pilots may be able to properly interpret products and gain understanding of product limitations.

Pilots may also benefit from assistance with preflight planning tasks. It can be very challenging to understand which products to access and how to apply information to a flight plan (Wiggins et al., 2002). Novice pilots in particular struggle with goal formation decisions and information application (O’Hare, et al., 1994). On the other hand, if pilots were able to receive help through this process, pilots could practice perceiving preflight tasks as experts do.
Repetition of effective preflight practices could give pilots the experience to gain stronger feature associations and may help pilots associate appropriate risk with weather phenomena. In turn, effective preflight practices will likely lead to effective inflight processes and decision-making. If pilots frame their weather-related diversions and alternate routes in terms of a “gain” instead of a loss, pilots may be less likely to continue into deteriorating weather. Therefore, through pilots practicing performing preflight planning using a “gains” mentality, this attitude may continue during inflight operations. Also, helping pilots plan diversions and alternate routes in case of emergency may encourage pilots to be more aware and proactive about hazardous weather inflight.

Therefore, the purpose of this study is to investigate whether the use of an aviation weather performance support tool would improve pilots preflight planning and inflight behavior.

Aviation Weather Preflight Performance Support Tool Literature Review

Automation and decision support tools have been applied to the aviation field; however, the application has been used primarily for navigational and aeronautical tasks. There is limited research on applying information and decision automation application to aviation weather planning and decision-making. It is possible that by applying automation and decision support tool technology to aviation weather interpretation and planning, pilots’ preflight and inflight performance may improve. This section will review automation and decision support tool literature to determine which aspects and components will aid in assisting with the GA weather problem.

Automation. Automation has been defined as the employment of automatic equipment into manufacturing or other processes. Automation levels and stages are used together to describe automated systems and tasks, and a particular system or process can be automated on varying
levels and types of automation. Automation levels range from low to high automation (Parasuraman, Sheridan, & Wickens, 2000). Hence, the automation type has four stages that mimic the information processing model, sensory processing, perception/working memory, decision-making, and response selection.

The first stage describes automation applied to information sensing and registration processes. These processes and tasks involve sensory receptor, sensory processing, preprocessing, and selective attention (Parasuraman, Sheridan, & Wickens, 2000). For instance, an example of a task in this stage would be the ordering or sequencing, information, such as the ordered response received from a Google search. In this task, automated algorithms sense the desired information from the user’s search term, and organize the information according to the most relevant information. At the very lowest level, this automation stage could represent the sensing of information, such as a temperature reading on a thermometer. This level of assistance automation could help prevent pilots from missing vital weather information. That is, previous research suggests that information acquisition is a task particularly difficult for novice/intermediate GA pilots. However, when completing the preflight process gathering weather information is crucial to an effective preflight weather plan. Automation could help guide pilots on which weather products to access for preflight.

The second stage of automation is processing and integration of information. This stage applies inferences to information, allowing for prediction (Parasuraman, Sheridan, & Wickens, 2000; Baddeley, 1996). For instance, when users begin to enter a search term into Google, Google usually offers suggested terms to assist with their search. This function helps users better word their search terms, which in turn, can help users get better results. This stage of automation is also used in aviation weather. For instance, when sensors collect raw visibility and ceiling
information, such as “4 statute miles” and “overcast at 3,000 ft”, the code can sense this information and translate it into flight category, IFR or VFR. This may help eliminate error and provide assistance to novice pilots who are still learning flight category criteria.

The third stage of automation mirrors the decision-selection stage of the information processing model, where a decision is chosen from decision options (Parasuraman, Sheridan, & Wickens, 2000). Applying this stage of automation could involve varying levels of automation. A low level of automation would suggest action(s) to the user, whereas high levels of automation would make the decision. This level of automation is rarely used in aviation tools. However, one example could be the autopilot function when the system makes decisions about how to mitigate shifts in altitude and direction from environmental stimuli. Autopilot systems take into account weather phenomena, such as winds and pressure, and select the most efficient way to stay on course.

Lastly, the fourth stage “action implementation,” describes the task of completing a decided action (Parasuraman, Sheridan, & Wickens, 2000). This stage is analogous to the action implementation step in the information processing model (Bennett & Flach, 1992). During this stage, instead of the human operator performing the action, automation uses mechanical hardware and software to execute the decided task. One primary example of automation stage in aviation is autopilot. Autopilot often decides and implements actions to navigate in response to environmental stimuli (Parasuraman, Sheridan, & Wickens, 2000).

The levels and stages can be combined in one system, with a system having multiple levels and stages of automation to meet the various system demands (Parasuraman, Sheridan, & Wickens, 2000). For instance, consider the product “Google Home” (2018). Google Home has varying levels of automations to meet different user needs. Google Home can complete action
implementation by executing a user demand, such as a user requesting a song to be played, or Google Home could perform decision selection and action implementation. The user could request Google Home to play a Jazz song and Google Home would select a Jazz song and play it. Furthermore, effective application of the various levels and stages of automation to various tasks is crucial for effective human and system performance.

Automation levels and stages have numerous implications for human and system performance (Parasuraman, Sheridan, & Wickens, 2000). Previous research has investigated automation’s effect on four main human performance areas: mental workload, situation awareness, complacency, and skill degradation (Parasuraman, Sheridan, & Wickens, 2000). First, consider the effect of automation on mental workload. Specifically, well-designed “information automation” can reduce operator mental workload so that tasks can be performed more effectively (Parasuraman, Sheridan, & Wickens, 2000). Data summaries, information highlighting, and integration can all help reduce operator workload. Information automation has been applied to different fields of aviation such as air traffic control. For example, air traffic control now has data blocks that features airplane speed, direction, and aircraft type on their scope of airplanes in their sector. This reduces workload because the information is automatically fed to the operator’s screen, instead of the operator having to ask the pilot for the information. Information automation can present information in a useful manner by priority and relevance which can help the operator make better decisions.

However, if levels and stages are incorrectly applied to tasks, automation can lead to an increase in mental workload. Specifically, automation can add more mental workload if it is difficult to start and engage, and this could lead to more costs to human performance, such as
situational awareness, complacency, and skill degradation (Parasuraman, Sheridan, & Wickens, 2000).

Additionally, situation awareness should be considered when applying automation to tasks. Previous studies found that decision automation could limit operators’ situation awareness of the current operational environment. As a result, operators may be less aware of changes in their environment and unequipped to handle hazardous situations (Kaber, Omal, & Endsley, 1999; Endsley, 1996; Endsley & Kiris, 1995; Sarter & Woods, 1995). Therefore, when applying decision automation instead of allowing the operator to be passive, engineers should attempt to engage the operator to preserve situational awareness.

Another issue is the effect of automation on human complacency. If a high level of automation is applied to a task, the operator could over-rely on the automation and fail to identify automation errors (Wiener, 1981; Parasuraman, Molloy, & Singh, 1993). For instance, when using autopilot, pilots may become complacent and fail to remain vigilant of the systems’ status. This could leave room for possible erroneous performance. Complacency may also be prevalent when applying automation cueing (i.e., highlighting important cues to attract the operator’s attention). Previous studies have identified that the employment of automated cue guiding could result in operators paying inadequate attention to the “un-cued” components of the task (Yeh, Wickens, & Seagull, 1999). Therefore, although operators may improve in some previously overseen aspect of a task, they may underperform on certain areas of a task they once mastered. Research suggest that the effects of complacency are greater with decision automation rather than information automation. Additionally, when automation is completely reliable, both information automation and decision automation equally increase human behavior (Crocoll & Coury, 1990). However, unreliability seems to negatively affect human behavior.
Automation research has also investigated automation effects on skill degradation. Decision automation could eventually lead to operator skill degradation (Rose, 1989). This could be prevalent especially with respect to disuse of automation (Kaber, Omal, & Endsley, 1999).

When considering the multiple possible costs of high level decision automation, complacency, situational awareness, and skill degradation, it is imperative to appropriately apply automation to avoid these potential performance costs. These costs could be particularly harmful in high risk and high workload environments, such as general aviation. Therefore, automation reliability and trust should be considered before automation assignment in aviation (Parasuraman, Sheridan, & Wickens, 2000).

**Trust and Reliability.** Trust is another important construct to monitor when automating tasks. Depending on the reliability of automation and the nature of the tasks, trust can have an effect on human performance (Lee & See, 2004). Operators can have a lack of trust in an automated system, and instead of working with the automation, operators can waste time double checking the automated systems’ performance (Lee & See, 2004). This could lead to error, higher workload, and hazardous events. However, it is also possible operators can over rely on automation, which can also lead to erroneous behavior (Lee & See, 2004). It is important to produce reliable automation; research suggests that trust increases with unreliability and false alarms (Lee & See, 2004).

In summary, previous studies warn that the potential benefits of automation may also come with limitations or costs of applying automation. When applying automation, it is important to be cognizant of automation costs and mitigate them effectively. Carefully designed automation, however, may prove a useful tool to assist GA novice/intermediate pilots to understand aviation weather ant implications for flight. Since novice/intermediate pilots struggle with information
acquisition, comprehension, and application, perhaps applying the appropriate level of automation to various aviation weather tasks would help improve pilot preflight planning. Automation may be best applied through a decision support tool. Decision support tool automation assists the user with completing tasks and making decisions and have been used in aviation and healthcare to help guide operators through tasks for years. The next section will review decision support tool literature to investigate the feasibility of applying this technology to aviation weather product interpretations, application, and preflight planning.

**Decision Support Tools.** Decision Support Systems (DSS) are computer-based systems that aid operators in problem solving and decision-making tasks (Power & Sharda, 2009). In order to assist the user with making informed decisions, these systems often use a combination of data, documents, knowledge, and model algorithms. Essentially, DSS are designed to support and facilitate the decision process and adapt to fit the operator’s needs. Although DSS use automation to help the user make a decision, unlike decision automation, DSS do not make the decision for the operator.

While various types of DSS that help support decision-making exist, the particular type of DSS of interest in the current study are knowledge driven DSS (Power & Sharda, 2009). Instead of using data and models like other DSS, knowledge driven/ expert DSS help provide operators with information concerning their task and suggest action to the operator. A knowledge driven DSS provides specified expertise in a certain topic and is equipped to help the operator understand and solve problems within that field. In addition to the data, document and knowledge driven DSS, there are also general and function-task specific DSS (Power & Sharda, 2009). Function-task specific DSS are developed to support tasks and decision-making in a particular domain. This type of DSS is most useful when used to assist an operator to complete a
routine process or decision task. In contrast, general DSS support very broad tasks such as business management and business intelligence. Both function-task specific and general DSS can be data, document, model, or knowledge driven (Power & Sharda, 2009). The DSS of primary interest for this paper is *Function-task specific knowledge driven DSS* for aviation weather preflight planning.

Although DSS have been theorized to help operators through the decision process, there are challenges associated with introducing DSS into existing complex systems and/or tasks (Cohen, Parasuraman, Serfaty, & Andes, 1997). Misuse of the DSS can actually decrease human machine performance and introduce new errors (e.g., over reliance, complacency and a degraded skill, degraded vigilance). How operators use DSS can be heavily influenced by under-trust and over-trust of the system (Lee & Moray, 1992; Roth, Bennett, & Woods, 1988). One reason underlying the problems with trust between operators and DSS can be a result of a poorly developed mental model of how the DSS functions (Parasuraman & Riley, 1997). Fortunately, effective training on how to properly use DSS to assist with the decision process improves efficient human machine interaction with DSS (Cohen, Parasuraman, Serfaty, & Andes, 1997).

Another factor for a decrease in performance could be “cognitive misers.” Cognitive misers, are individuals who try to perform tasks with the least amount of cognitive work as possible. This can lead to operators using DSS as a sort of heuristic and decrease the operators’ system situational awareness and decision-making. In these situations, human-machine teamwork can actually decrease productivity, and cause the human operator to be less vigilant and perform with less effort (Cohen, Parasuraman, Serfaty, & Andes, 1997).

*Clinical Decision Support Systems in Health Care.* Despite the challenges associated with Decision Support tools/systems, knowledge-based decision support systems, clinical decision
support systems (CDSS) have been used in the medical field for the last 40 years (Barness, Tunnessen, Worely, Simmons, & Ringe, 1974; Miller, Chanllinor, Masarie, & Myers, 1986). These systems were designed to aid physicians and assistants with diagnosis and other patient care processes. CDSS are usually composed of three primary components, the knowledge base, inference or reasoning, and the user interface. The “knowledge base” consists of relevant content and knowledge in an IF, THEN, and ELSE format. The “reasoning” component contains algorithms for combining rules and exceptions to assist the user. Lastly, the interface is how the user sends information to and receives information from the decision support system. System feedback can vary from recommendations, to alerts, and other information.

Although, the medical field has applied CDSS to medical operations, there is limited research investigating the effectiveness of CDSS. There is also a lack of research investigating the exact impact and use of clinical decision support tools. For example, KLAS (2003) reviewed a site that used COPE systems that employed CDSS to apply alarms, decision aiding logic, and knowledge systems to reduce errors during ordering process. Results indicated that many sites only used ten or less alerts during order processes. This resistance to using alarms or alerts is a common response to automation and alarms, as users may distrust the system’s suggestions and alerts when they differ from the operators own assessment.

Eccles, McColl, Steen, et al., (2002) analyzed the effects of a guideline-based decision support system in 31 general practice settings. Results indicated the CDSS system intervention had minimal improvement on health outcomes. A more detailed investigation revealed, practitioners failed to use the CDSS. In fact, practitioners often overrode and ignored system alerts and suggestions. This lack of use or misuse of CDSS systems could be linked to poor system design and inadequate CDSs training. Teich et al. (2000) suggests that CDSS are most
effective when they align with the physician’s mental models and do not require them to change their processes.

Additionally, there is also significant lack of research evaluating the effectiveness of CDSS that are broadly applied. Dombal (1991) and Adams, Chan, Clifford et al., (1986) investigated the effectiveness of Leeds University CDSS for acute abdomen diagnosis. Additionally, results indicated that at the original site, where the decision aid was developed and implemented diagnosis, decision-making and patient outcome improved. Although the system performed well in the original local site of introduction, once applied to other sites the success rate decreased. However, despite the lack of literature regarding decision support tool effectiveness, The Office of the National Coordinator (ONC) for health information technology reported that 74 percent of physicians use a clinical decision support system the assists with drug interactions and effects and 57% use at least one clinical decision support tool that provides guidance and suggestions for screening tasks. This gap between research literature and commercial use of DSS is relevant in the aviation field and other fields as well.

**DSS Design.** DSS design has implications for the effectiveness of the tool for the current study. It is crucial that DSS present task-related information in a useful and strategic manner, using heuristics strategies (e.g., using an “elimination by aspect” strategy to develop the interface design), that assist in user engagement and decision error avoidance (Karim, Hershauer, & Perkins, 1998). Although, implementing heuristic strategies in DSS design could prove useful, it is imperative that the implemented heuristics strategies match the needs of the user base. Arbitrarily assigning heuristics strategies to DSS design could result in a mismatch between use needs and system design and could promote more hazardous performance (Vicente, 1999).
In the aviation field, Wiggins & Bollwerk (2006), investigated user preferences for including heuristics information DSS design. During their study, participants were tasked to evaluate various airports and their features in order to decide the optimal airport for flight safety and scenario goals. While completing this task, participants had the opportunity to interact with three different heuristic DSS interfaces. Afterwards, participants were asked which interface they preferred and which one they would use again. Results indicated interface choice was unrelated to decision accuracy, experience, demographic information, or information presentation effectiveness. Instead, interface preference was related to user perceived difficulty in comparing alternative airport features (e.g. runway information, landing fees, and maintenance facilities). Additionally, interface choice did indicate differences in information acquisition efficiency. Specifically, the “elimination by aspects” design took users more time to compare feature options than the “frequency and majority of confirming dimensions” interface did (Wiggins & Bollwerk, 2006).

To further investigate user differences and interface preference, Harris & Wiggins (2008) investigated whether polychronicity (i.e., the preference for completing multiple tasks concurrently, instead of sequentially) could provide insight on user preference for heuristics preferences for DSS interfaces. However, results indicated there was no relationship between polychronicity and DSS interface design. Similar to Wiggins & Bollwek (2006), results indicated participant chose the interface that seemed less difficult, elimination by aspects (Harris & Wiggins, 2008).

Perry, Wiggins, Childs, & Fogarty (2013) furthered this research by investigating the effect of various decision support system interface designs on inexperienced firefighters’ decision-making. For this study, participants were tasked with completing a decision task. The
experimental conditions in this study included training (training vs. control), and DSS interfaces (quasi-analytical & intuitive), and the amount of control users had over the displayed information (pre-configured & self-configured). The two interface designs used in the study were the quasi analytical interface (access to information for 8 cues) and the intuitive interface (access to information for 3 cues). Participants were separated into two interface design groups and the control (no training) and training groups. Although training and DSS interfaces alone did not impact decision accuracy, pilots who received the intuitive interface, training and pre-configuration had improved decision accuracy. Overall their results indicated that decision support systems influenced users to perform better decision accuracy and efficiency when the system is preconfigured and effectively highlights important cues.

Lastly, Wiggins’ team reevaluated user preference and accuracy in using various decision support tool interfaces in various stressful conditions (Morrison, Wiggins, & Porter, 2010). During the study, 40 crime scene investigators used DSS to access information and make decisions. For the first phase participants were introduced to each DSS interface. There were three DSS interfaces available: paired options-moderate control (majority of confirming dimensions), all options-full control (elimination by aspects), all options–limited control (satisficing) (Morrison, Wiggins, & Porter, 2010). During the second phase, participants chose their preferred DSS interface and used that interface to complete decision-making tasks with varying levels of time pressure. Results from the study revealed that “all options-full control” was the preferred DSS interface amongst users in in the low time pressure condition (Morrison, Wiggins, & Porter, 2010). While the preference for the all options-full control was not significant, this option was preferred during the high-pressure condition. The results support the
theory that user perception of difficulty of use and autonomy within the DSS were more valued than efficiency for preference in DSS interface design (Morrison, Wiggins, & Porter, 2010). Wiggins and his teams’ work investigated applying different heuristic-based strategies into decision support tool development. Decision support systems (DSS) have the capability to relieve workload, reduce decision related errors, and assist with information acquisition (Workman, 2005). However, as indicated through prior research, without considering user autonomy, transparency, and adaptability in DSS design, automation limitations may outweigh the benefits. Hopefully through including these design elements, DSS will have better usability and user acceptance.

**DSS for Preflight Weather Tasks.** Previous research suggests when implementing decision support tools or decision aids to consider several key variables: the level of automation, decision aid content/ subject matter expert involvement, usability and adaptability. These factors will be discussed with respect to applying DSS to weather preflight tasks to improve preflight and inflight performance.

As described earlier, during the preflight process, pilots have difficulty with the task of product interpretation and selection. If automation were applied to this task, a useful support system would suggest which weather products are essential for the pilot’s flight plan. The support system could also prompt the pilots to think about the weather information the way an expert would. That is, by offering tips and guidance, the support system could function like a coach or smart checklist to ensure the novice pilot is performing efficient information acquisition and conceptualizing the retrieved information. This type of automation would be mid-level information acquisition and analysis, where, the automated system is suggesting how novice pilots should access and interpret weather products. This type of automation is more effective
than high level type decision automation, where the automation makes decisions for the user (Shimon, 2009).

Unfortunately, a possible negative effect of a DSS could be complacency and skill degradation (Wiener, 1981; Parasuraman, Molloy, & Singh, 1993). In terms of aviation weather, a novice pilot may be over-reliant on the support tool for assistance with interpreting weather products and attempts to interpret weather products without the support of the preflight decision aid, their performance may decrease instead of increase and, overtime, the novice pilot could become too dependent on the decision support tool. However, research suggests that complacency and overreliance issues are more common with decision automation rather than information automation (Crocoll & Coury, 1990). And helping pilots by providing weather information automation could be well worth the risk of overreliance.

Another way to mitigate risks with automation is to train users how to use the tool effectively. For example, when considering a decision support tool to aid low experienced pilots with the preflight process, the pilot must know how much assistance the system is able to provide. Pilots should not rely on the system to make decisions or provide feedback on their decisions if the systems’ only purpose is to provide informative suggestions. A discrepancy between user expectations and system performance can cause confusion and error prone activity (Cohen et. al, 1997). However, if users (in this case pilots) are trained how to use the product, the decision support tool could considerably reduce error and improve operations (Cohen et. al, 1997).

Content validity and user-centered design are also crucial for supporting human and decision support tool performance (Cohen et. al, 1997). Function and task specific decision support tools
use “experienced knowledge” to assist operators when performing tasks (Shimon, 2009). Therefore, the content validity of the knowledge-based information is crucial for improved performance. For example, a preflight decision support tool requires correct aviation and meteorological “knowledge” to help the pilots make informed decisions concerning their flight. If the system lacks accurate aviation or weather knowledge principles, it may leave the novice user unprepared to perform their tasks effectively. As a result, a tool that was designed to decrease workload and increase performance could actually hinder safe flight activity and introduce even more confusion to an already complicated environment. Therefore, multi-disciplinary teams are essential for ensuring content validity and system design. Both expert pilots and meteorologists are needed to verify the system is capable of providing proper guidance for novice users.

Usability and human-centered design are important principles to consider during decision support tool development (Cohen et. al, 1997). Technology is too often applied to complex environments without taking the user into consideration. In the GA weather community, vendors continually attempt to improve technology to assist with pilots’ preflight and inflight performance. However, new weather technology such as RADAR and overlaid dynamic maps may actually encourage hazardous flight activity rather than prevent it (Latorella & Chamberlain, 2002; Yuchnovicz et al., 2001; Beringer and Ball, 2004). Previous research indicates that pilots with dynamic weather in the cockpit actually flew closer to degrading weather, compared to the control group (Latorella & Chamberlain, 2002; Yuchnovicz et al., 2001; Beringer and Ball, 2004). Instead of repeating previous mistakes, developers of aviation weather decision support tools must consider the pilot needs early in the design process. Increased system usability could assist with system transparency and trust (Cohen et. al, 1997). Furthermore, the more user
friendly the system is, the more transparent the systems’ functions will be for the pilot.

Research also suggests that facilitating decision support tool automation customization could improve system transparency and human-machine interaction (Billings & Woods, 1994). For instance, if a novice pilot needs assistance with risk assessment but was improving on their product interpretation skills, the pilot could adjust the preflight decision support tool automation to focus on risk assessment rather than product interpretation (e.g., low automation on product interpretation and medium automation on risk assessment tasks). This way, the pilot can practice using their skills during product interpretation and receive more assistance with risk assessment. When implemented correctly, system customization could help specialize the decision support tool to effectively meet the users’ knowledge and skill deficiencies (Cohen et. al, 1997).

**Overall Literature Review Summary**

GA weather-related accidents have a sustained a very high fatality over the last 30 years. Further investigation into the accident data revealed, VFR into IMC accidents account for the majority of weather-related fatalities. Furthermore, low experienced private pilots have been hypothesized to have low aviation weather knowledge, poor weather SA, and inadequate aviation weather risk perception. Although there is limited research that assesses GA pilots’ weather knowledge and situation assessment, research claims poor aviation knowledge may be the underlying reason for poor pilot judgement, risk perception, and inadequate situation assessment. As a result, low experienced pilots may be incapable of proper preflight planning and weather avoidance due to their poor feature and cue association development. This may have severe consequences for inflight operations and may lead to fatal weather-related accidents. Moreover, a poor understanding of weather products and theory, may result in pilots having a limited mental map of inflight weather. Consequently, a lack of weather situational awareness may lead to
poor decision-making and error. It may be beneficial to consider new methods towards improving low experienced pilots’ aviation weather practices. Perhaps by providing pilots with a performance support tool to aid them in the preflight process, pilots’ understanding of weather, decisions, and inflight weather-related behavior may improve. Thus, decision support tool technology could assist novice/intermediate pilots through the aviation weather preflight process.

To ensure the effectiveness of the Preflight Decision Support Tool, developers should consider decision aid content/subject matter expert involvement, usability, and adaptability. Additionally, possible automation limitations, such as situational awareness decrements, complacency, and skill degradation, should be carefully monitored. If all of these factors are considered, a DSS could be an effective option for assisting low hour novice pilots with preflight and inflight performance and weather avoidance.

The purpose of this study is to investigate the effect of a Preflight Weather Decision Support Tool (PWDST) on participants’ preflight performance and inflight performance. For the purpose of this study, preflight and inflight performance will be operationally defined by three main principles, weather conditions assessment, risk assessment, and decision-making.
Therefore, this study will investigate the following hypotheses (see figure 3):

**Hypotheses Relating to Preflight**

The Preflight Weather Decision Support Tool will have a positive effect on participant’s preflight performance. Participants who use the tool will have better preflight performance than participants without the tool: Information Acquisition, Weather Awareness, Risk Perception, and Decision Making (see figure 4).
Figure 4. Preflight Hypothesis Model H1, H2, H3, H4

- **Hypothesis 1 (H1).** Participants who use the tool will access a greater amount of key products during preflight than participants without the tool.
  - **IV:** The Tool
  - **DV:** The percentage of crucial weather products that were accessed.

Participants who use the tool will demonstrate a more accurate understanding of present and trending weather along the flight route than those participants who do not use the tool. Specifically:

- **Hypothesis 2a (H2A).** Participants who use the tool will score higher on Subcategory *Weather Phenomena* in the Weather Assessment on the Post Preflight Survey than those participants who do not use the tool.
  - **IV:** The Tool
  - **DV:** Percent correct score on Subcategory Weather Phenomena Category
Hypotheses Relating to Inflight Survey

- **Hypothesis 2b (H2B).** Participants who use the tool will score higher on Subcategory Weather Trending in the Weather Assessment on the Post Preflight Survey than participants who do not use the tool.
  
  - **IV:** The Tool
  
  - **DV:** Percent correct Score on Subcategory Weather Trending on Post Preflight Survey

- **Hypothesis 3 (H3).** Participants who use the tool will have more accurate risk perception concerning weather along their flight route than participants who do not use the tool. Participants who use the tool will score higher score on Risk Perception on the Post Preflight Survey than participants who do not use the tool.
  
  - **IV:** The Tool
  
  - **DV:** Percent correct score on Risk Perception on the Post Preflight Survey

- **Hypothesis 4 (H4).** Participants who use the tool will make safer decisions during the preflight process than participants who do not use the tool. Participants who use the tool will score higher on Decision Making on the Post Preflight Survey than participants who do not use the tool.
  
  - **IV:** The Tool
  
  - **DV:** Decision Making Go or no-go decision

**Hypotheses Relating to Inflight**

Participants who used the tool will have an output that will enable them to be more aware of weather conditions along their flight route than participants who do not use the tool (see figure 5).
Specifically:

**Hypothesis 5a (H5A).** Participants who use the tool will score higher the Weather Subcategory *Inflight Weather Phenomena* on the post-inflight survey than participants without the tool.

- **IV:** The Tool (Output)
- **DV:** Percent correct score on Subcategory Weather Phenomena on the Post Inflight Survey

**Hypothesis 5b (H5B).** Participants who use the tool will score higher on the Weather Subcategory *Inflight Weather Trending* in the post-inflight survey than those participants who do not use the tool.

- **IV:** The Tool (Output)
- **DV:** Percent correct score on Subcategory Weather Trending in the Post
Inflight Survey

Participants who use the tool will have a better understanding of weather risks along their flight route than participants who do not use the tool. Specifically:

- **Hypothesis 6 (H6)**. Participants who use the tool will spend less time flying into degraded weather conditions than those participants who do not use the tool.
  - **IV**: The Tool (Output)
  - **DV**: Decision Making (Time Weather IMC – how long participants flew into IMC)

**Relationship Between Preflight & Inflight Measures**

- **Hypothesis 7 (H7)**: There will be a significant prediction of Decision Making by, Percentage of crucial weather products accessed, Weather Phenomena, Weather Trending, and Risk (see figure 6).
Figure 6. Inflight Hypothesis Model H7

- **Hypothesis 8 (H8):** There will be a significant prediction of Time Flown into IMC by, Weather Phenomena, Weather Trending, Weather Change (see figure 7).
**Mediation Model**

- **Hypothesis 9 (H9).** The impact of PWDST on Time Flown into IMC is effected by The effect of PWDST on Preflight risk on Time Flown Into IMC (see figure 8).
Figure 8. Inflight Hypothesis Model H9
CHAPTER 2

METHODS

Experimental Design

The study will be a between subjects, 2 group design. The purpose of this study is to assess the effect of a preflight decision support tool on novice pilots’ preflight and in turn, inflight performance. The experimental group will receive the preflight decision support tool, whereas, the control will not (see figure 9).

![Preflight Decision Support Tool Diagram](image)

*Figure 9. This figure is a pictorial representation of the experimental design.*

Participants

Seventy-eight private pilots, 71 male and seven female with ages ranging from 18 to 30 \((\text{Mage} = 20.15, \text{SD} = 2.56)\) without instrument ratings, were recruited from a Southeastern US university. A total of 41 VFR private pilots were randomly assigned to the control group (no preflight decision tool) and 37 VFR private pilots were assigned to the experimental group.
(preflight decision tool). This study was approved by the Embry-Riddle Aeronautical University Institutional Review board for participant protection and safety. For incentive, participants received $100 for participation upon completion of the study.

Tables 3-5 contain more information about flight training, flight hours, and weather experience.

Table 3. Type of Flight Training Received

<table>
<thead>
<tr>
<th>Type of Flight Training</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 61</td>
<td>34</td>
</tr>
<tr>
<td>Part 141/142 Collegiate</td>
<td>7</td>
</tr>
<tr>
<td>Part 141/142 Non Collegiate</td>
<td>36</td>
</tr>
<tr>
<td>Military</td>
<td>1</td>
</tr>
</tbody>
</table>

The majority of pilots completed their training at a Part 141 flight non collegiate flight program and a Part 61 fixed based operation training facility (FBO).

Table 4. Mean and Median Total and Instrument Flight Hours

<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>Flight Hours M (SD)</th>
<th>Median</th>
<th>Instrument Hours Actual M (SD)</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (No PWDST)</td>
<td>41</td>
<td>99.96 (40.34)</td>
<td>97.00</td>
<td>2.19 (4.30)</td>
<td>0.30</td>
</tr>
<tr>
<td>Experimental (PWDST)</td>
<td>36</td>
<td>98.40 (34.08)</td>
<td>92.5</td>
<td>1.78 (3.00)</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Table 4 displays means and medians for total and instrument flight hours, as shown, both groups have very limited instrument inflight experience.
Table 5 displays how many participants have encountered Instrument Meteorological Conditions (IMC) while flying a VFR flight plan, both the control and experimental groups have had limited VFR into IMC experience.

Table 6 depicts both the control and experimental groups’ aviation weather knowledge, both groups scored relatively low, under 50 percent correct, on the Aviation Weather Knowledge Exam.

**Independent Variable Related Materials**

The following materials were used in this study: Preflight decision support tool, Tool Training Video, and Control Video.
**Preflight Weather Decision Support Tool.** The Preflight Weather Decision Support Tool was wire-framed using Google Drive App Draw.io and the high fidelity mockup was created with AXURE software student license. The purpose of this tool is to guide users through the preflight process and improve preflight and inflight performance. The Preflight Weather Decision Support Tool (PWDST) is comprised of three main components; the preflight guide, the personal minimums sections, and the risk assessment and checklist output.

The personal minimums section prompts users to set personal minimums for VFR flight. This section is modeled from the FAA’s suggested personal minimum format and has ten items for pilots to consider. For each item the pilot must identify their safety threshold. The PWDST features suggested minimums ranges for each item, and alerts the user if their limit is outside the suggested range. After completing all the fields successfully, the user will have a complete record of their safe VFR minimums.

The preflight guide component guides the user through a set of weather products essential for effective preflight planning. For each product the PWDST will have tips for product interpretation and application, a form for note taking, and prompting decision-making questions. The product interpretation assistance feature uses automation and usability principles to provide legends and highlight key areas on weather products to simplify product interpretation.

After guiding the user through all the essential weather products, the user is brought to the risk assessment and output section. This section summarizes the users notes gathered from the accessed weather products. During this stage, the information is presented, and the tool helps the user assign risk to reported weather phenomena. After assigning risk to the various weather conditions along their flight route, the app helps the user decide whether to embark on the flight or not.
**PWDST Training Video.** This video took 30 minutes for participants to complete and it was developed using Microsoft Video Maker. The purpose of the training video is to guide users through the main components of the PWDST. The video illustrates how to navigate the tool’s preflight guide, the personal minimums sections, and the risk assessment and checklist output.

**Control Video.** This video took participants 30 minutes to complete and was retrieved from YouTube. The video reviews KAEL and KDTL airport information, including runway information, airport facility information, and NOTAMS.

**Experimental Task: Simulated flight scenario**

Participants performed a preflight and inflight of one aviation weather scenario. The flight scenario was a VFR into IMC scenario. In the scenario, the scheduled flight route started at the departure airport, KAEL, MN, and ended at the destination airport, KDTL, MN. The flight was estimated to last for 1 hour and 30 minutes. The aircraft used in this simulation was a Cessna 172 G100, on a VFR direct GPS flight route. Table 7 shows the flight times and description.

*Table 7.*

**Flight Route.**

<table>
<thead>
<tr>
<th></th>
<th>VFR into IMC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location:</strong></td>
<td>KAEL, MN to KDTL, MN</td>
</tr>
<tr>
<td><strong>Time:</strong></td>
<td></td>
</tr>
<tr>
<td>Preflight</td>
<td>2200Z (5 PM CDT, 6 PM EDT)</td>
</tr>
<tr>
<td>Departure</td>
<td>2300Z (6 PM CDT, 7 PM EDT)</td>
</tr>
<tr>
<td>Destination</td>
<td>0045Z (7:30 PM CDT, 8:30 PM EDT)</td>
</tr>
</tbody>
</table>
Sky condition start clear with 10 statute miles visibility. Midway at KPEX conditions clouds drop to overcast 800 ft, with thunderstorms in the vicinity and fog.

**Preflight.** The purpose of this preflight was to closely mimic actual preflight processes. Pilots were provided the flight information, including route, departure arrival times, NOTAMs, additional airport information, and all weather information. Historical weather products were collected from the Aviation Weather Website and the Pilot Training System website. A mock Aviation Weather Center website was designed using AXURE software to present all the weather needed for the preflight. Weather products featured on the website include:

- **METARs**
- **TAF**
- **Surface Analysis Chart**
- **Surface Prognostic Charts**
- **Low Level Significant Weather**
- **Convective SIGMET**
- **G-AIRMET**
  - **ZULU**
  - **Freezing level**
  - **Sierra**
In addition to the weather information, pilots were also provided with Airport Diagrams, ASOS and AWOS Frequencies, E6B Electronic Flight Calculator, Aeronautical Sectional Charts, Chapter 5 of the Cessna 172 Aircraft Manual, and the ERAU Navigational Log Sheet to complete the preflight scenario. Pilots were instructed to perform Preflight Planning tasks, as if they were actually about to embark on the flight.

**Inflight Simulation.** The flight scenario was designed to present accurate yet changing weather conditions. As displayed in Table 8, the weather conditions during the flight changed somewhat from the weather forecasts and observations available to the pilot during pre-flight. At the beginning of the simulated flight, pilots experienced VFR conditions and as the pilot approached KAXN, weather conditions started to deteriorate with lowering clouds and decreased visibility. When pilots reached KADC, weather conditions were IMC with thunderstorms and rain in the area, and pilots were required to either divert or fly IFR operations. Once pilots reached within 5 nautical miles of the destination, KDTL, the simulation ended.

*Table 8.*

Flight Route Weather Development

<table>
<thead>
<tr>
<th>Airport</th>
<th>Preflight METARs (AGL)</th>
<th>Preflight Forecasted Outlook (TAF)</th>
<th>Simulated WX (AGL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAEL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Flight Simulator. The desktop flight simulation was implemented with PREPAR3D, version 3 (Lockheed Martin, 2017). The Active Sky (Active Sky 2016, Version 3) add-on weather was used to depict high fidelity weather within the PREPAR3D simulation environment.

**Dependent Variables/Measures**

For the purpose of this study, performance was defined in terms of risk assessment, weather interpretation/application, information acquisition, and decision-making. A combination of observation tools and surveys were used to measure these constructs in both preflight and inflight portions of the scenario.
**Survey Measures.** All surveys were developed online using the Qualtrics survey software. The participant background surveys (see below) were provided online, and participants completed online surveys on their device of choice.

All the measures were separated into three primary groups Background Surveys, Preflight Surveys, and Inflight Surveys. Table 9 displays survey measure and cronbach alphas.

*Table 9.*
Scales Means & Reliability

<table>
<thead>
<tr>
<th>Scale</th>
<th>Item Number</th>
<th>Cronbach's $\alpha$</th>
<th>$M$ (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Preflight Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preflight Weather Phenomena</td>
<td>8</td>
<td>0.71</td>
<td>85.6 (18.9)</td>
</tr>
<tr>
<td>Preflight Weather Trending</td>
<td>6</td>
<td>0.88</td>
<td>49.1 (39.3)</td>
</tr>
<tr>
<td>Preflight Risk</td>
<td>3</td>
<td>0.81</td>
<td>35.5 (40.7)</td>
</tr>
<tr>
<td>Post Inflight Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflight Weather Phenomena</td>
<td>6</td>
<td>0.73</td>
<td>62.6 (30.4)</td>
</tr>
<tr>
<td>Inflight Weather Trending</td>
<td>2</td>
<td>0.83</td>
<td>87.8 (30.4)</td>
</tr>
</tbody>
</table>

The purpose of the participant background surveys was to get a baseline measurement of participants’ flight experience, weather experience, product familiarity, confidence in knowledge of weather skills and principles, and risk assessment abilities. These include the following five surveys:

*Demographic Survey.* The demographic survey was composed of 85 items. The demographic survey items covered topics such as participant age, flight training, flight experience, weather training, and weather experience (see Appendix A).

*Product Usage Questionnaire.* The product usage questionnaire was comprised of 105 items (see Appendix B). The survey identified which weather products (i.e., observations and forecasts)
participants use the most often and how much participants value various weather products and weather product source information. First, participants were prompted to rate how valuable information is from each product and product source on a five point likert scale. Then participants were prompted to indicate which products/products sources they rely on for the most up to date weather information during preflight and while inflight.

*Self-Efficacy.* The self-efficacy questionnaire contained 105 items (see Appendix C). The survey focused on participant’s confidence in their knowledge, skills, and ability to access, interpret, and apply aviation weather information. For each item, participants were asked to rate their confidence on a scale from “0 Cannot do at all”, to “Highly certain I can do”.

*Weather Knowledge.* The weather knowledge assessment consisted of 45 multiple choice items, the topics covered include weather products interpretation, knowledge of product limitations, and ability to apply weather information. The questions are an adaption of the weather knowledge assessment developed by Blickensderfer et. al., (2017).

*Preflight Survey.* This survey measured risk assessment, weather interpretation/application, and decision-making after the pilot had completed the preflight and was ready to fly the simulation (see Appendix D). This survey prompted participants to predict how weather will develop and describe weather at the destination, en-route, and departure airport. Participants were also asked how risky the reported weather conditions is and their confidence in their risk assessment. Lastly, participants were asked about their decision to fly the flight route and whether they planned a diversion route and airport.

*Tool Training Quiz.* This quiz tested participants’ ability to navigate the PWDST as well as their perceived usability of the tool.
**Control Training Quiz.** This quiz tested participants on their knowledge of the information presented in the Control Video, including KAEL and KDTL airport information, runway information, airport facility information, and NOTAMS.

**Inflight Survey.** The post-scenario weather situation assessment survey was a retrospective survey (completed after flying the simulation) and measured participant risk assessment, weather interpretation/application, and decision-making regarding the inflight portion of the scenario (see Appendix E). This survey prompted participants to report decisions made during the inflight simulation and to describe weather observed during the inflight simulation at the destination, en-route, and departure airport. Participants were also asked to rate how risky their decisions were inflight, asked how risky the inflight weather conditions were, and their confidence in their risk assessment. Lastly, participants were asked about their decisions to get inflight weather, their flight path, and whether or not they decided to divert or not.

**Observational Measures**

Behavioral measures were used to assess performance for the preflight and inflight portions of the scenario.

**Preflight Observational Measures.** In order to measure information acquisition, the Ice Cream screen recoding tool was used to record information acquisition frequency and accuracy during the preflight scenario.

**Inflight Observational Measures.** Ice Cream screen recording tool was used to record the flight to later obtain the following inflight measures:

- **Total Flight Time in IMC:** This represents the total time during the inflight simulation scenario that participants flew in IMC.
• **PIREPs of Weather Change:** Participants identified and reported when weather changes significantly during the inflight simulation scenario.

Tables 10 and 11 display a summary of the survey and observational measures for preflight and inflight, respectively.

*Table 10.*

**Preflight Measures**

<table>
<thead>
<tr>
<th>Preflight Scenario Measures</th>
<th>Construct</th>
<th>Observation</th>
<th>Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather Product Knowledge/ Limitations</td>
<td>Weather Information Frequency</td>
<td>Ice Cream Screen Recording</td>
<td></td>
</tr>
<tr>
<td>Weather Awareness, Risk, Decision making</td>
<td>Preflight Survey</td>
<td>Qualtrics</td>
<td></td>
</tr>
</tbody>
</table>

*Table 11.*

**Inflight Measures**

<table>
<thead>
<tr>
<th>Inflight Simulation Scenario Measures</th>
<th>Construct</th>
<th>Observation</th>
<th>Tool</th>
</tr>
</thead>
</table>
Once participants arrived at the data collection site they were briefed. Each participant reviewed and signed an informed consent form. Then participants received an email with a link to all the background surveys, and participants completed all the surveys at home on the device of their choice. After completing the background surveys, the participants were scheduled for an appointment to complete the preflight and flight scenario. When participants arrived at their appointment they will again be briefed about the study. Next, participants completed the Aviation Weather Knowledge Exam. Then, the control group was given a 20-minute aviation video to watch. Whereas, the experimental group was trained on how to use the Preflight Decision Support Tool. After the training, the experimental group took a proficiency quiz and a usability assessment on the PWDST. After the control video, the control group took a quiz on the information in the aviation video. Afterwards, all participants completed the preflight scenario followed by the preflight survey. Then, all participants completed the inflight simulation followed by the inflight survey. Finally, each participant was debriefed and given their
compensation. See Table 12 for estimated completion times. At the completion of the study, participants were debriefed and compensated $100.00.

Table 12.

Procedures

<table>
<thead>
<tr>
<th>Phases</th>
<th>Time</th>
<th>Control Group</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>10 minutes</td>
<td>Brief</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 minutes</td>
<td>Consent Form</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 minutes</td>
<td>Demographics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 minutes</td>
<td>Self-Efficacy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20 minutes</td>
<td>Product Frequency of Use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total: 57 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 2</td>
<td>40 minutes</td>
<td>Weather Knowledge Assessment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20 minutes</td>
<td>Tool Training</td>
<td>Aviation Video</td>
</tr>
<tr>
<td></td>
<td>10 minutes</td>
<td>Tool Training Quiz</td>
<td>Aviation Video Quiz</td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
<td>Preflight Scenario</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 minutes</td>
<td>Post Preflight Survey</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
<td>Inflight Simulation Scenario</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>----------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 minutes</td>
<td>Post Inflight Survey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 minutes</td>
<td>Debrief &amp; Compensation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 3 hours

50 minutes
CHAPTER 3
RESULTS

Preflight Hypotheses Analyses

The first analysis assessed the Preflight Hypotheses one, two, and three.

A one-way, between subjects MANOVA was run to investigate the experimental and control group differences in preflight performance variables. Four dependent variables were included: Percent of Key Products Accessed, Preflight Weather Phenomena, Preflight Weather Trending, Preflight Risk. The independent variable is the PWDST. Tables 13 and 14 display the intercorrelations and descriptive statistics.

Table 13.
Correlations for Preflight Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Preflight Weather Phenomena</td>
<td>78</td>
<td>85.58</td>
<td>18.91</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>2 Preflight Weather Trend</td>
<td>78</td>
<td>49.15</td>
<td>39.28</td>
<td>0.18</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3 Preflight Risk</td>
<td>78</td>
<td>35.47</td>
<td>40.68</td>
<td>0.10</td>
<td>0.55**</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>4 Preflight Percent of Key Products Accessed</td>
<td>78</td>
<td>58.62</td>
<td>39.95</td>
<td>0.26*</td>
<td>0.22*</td>
<td>0.27*</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>5 PWDST a</td>
<td>78</td>
<td>0.47</td>
<td>0.50</td>
<td>0.30**</td>
<td>0.20</td>
<td>0.27*</td>
<td>0.91**</td>
<td>---</td>
</tr>
</tbody>
</table>

a 0 = Control Group (No PWDST) and 1= Experimental Group (PWDST). *p < .05 **p < .01

Table 14.
Mean Scores for PWDST on Preflight Dependent Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control Group</th>
<th>Experimental Group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Preflight Weather Phenomena</td>
<td>80.95</td>
<td>21.95</td>
<td>90.97</td>
</tr>
<tr>
<td>Preflight Weather Trend</td>
<td>43.25</td>
<td>39.83</td>
<td>56.02</td>
</tr>
</tbody>
</table>
The results of preliminary assumption testing were as follows:

- **Outliers.** Boxplots and Mahalanobis Distances were conducted revealing 12 univariate outliers and one multivariate outlier in the data set. Both univariate and multivariate outliers were not removed for this analysis.

- **Normality.** A Shapiro-Wilk's test for normality indicated all dependent variables (Percent of Key Products Accessed, Weather Phenomena, Weather trending, and Risk scores) were not normally distributed for both levels of the independent variable, PWDST ($p < .001$).

- **Multicollinearity & Singularity.** A Pearson's Correlation indicated there was no multicollinearity found amongst the dependent variables (see Table 13).

- **Linearity.** Scatterplots were developed to investigate linearity, and indicated that there were no linear relationships between the DVs.

- **Homogeneity of Variance-Covariances.** A Box's test of equality of covariance matrices was conducted to evaluate homogeneity of variance-covariances matrices, the assumption of homogeneity of variance-covariances was violated ($p < .001$).

- **Homogeneity.** The Levene's Test of Homogeneity of Variance revealed the assumption of homogeneity of variances was also violated ($p < .001$).

Due to the violation of the assumption of homogeneity of variance-covariance matrices, Pillai’s Trace criterion was used instead of Wilks’ lambda to evaluate multivariate significance (Olson, 1979; Tabachnick & Fidel, 2013, p. 254). The omnibus multivariate test results
indicated, that there was a statistical significant main affect of the PWDST on the combined DVs, $F(4, 73) = 89.43, p = .000$; Pillai’s Trace = .831; partial $\eta^2 = .831$.

![The Main Effect of PWDST on Preflight Performance](image)

**Figure 10.** Effect of PWDST on Preflight Performance

As a result of the assumption of equality of variances being violated for Preflight Weather Phenomena, Preflight Risk, and Percent of Key Products Accessed, a more conservative alpha level of .0125 was used for determining significance in the follow-up univariate $F$-test.

When the results for the DVs were considered separately with univariate ANOVAs, there was a statistical significant main effect of the PWDST on Preflight Weather Phenomena Score ($F[1, 76] = 356.12, p = .007$, partial $\eta^2 = .09$) and Percent of Key Products Accessed ($F[1, 76] = 356.12, p = .000$, partial $\eta^2 = .82$). Additionally, results indicated there was not a statistically significant main effect of the PWDST on Preflight Risk ($F[1, 76] = 356.12, p = .018$, partial $\eta^2 = .072$) and Weather Trend ($F[1, 76] = 356.12, p = .085$, partial $\eta^2 = .038$). Bonferroni Post Hoc tests revealed that participants that used the PWDST scored significantly higher on Preflight Weather Phenomena ($M= 80.18$, $SD = 21.83$, $p = 0.007$) and accessed a statistically significant
higher Percent of Key Weather Products (M= 96.56, SD = 10.35, \( p < .001 \). There were no other significant findings (see figure 10).

As a result, there is partial support of the preflight hypotheses (H1, H2a, H2b, H3). We accept the alternate hypothesis one and hypothesis 2(A) but do not reject the null hypothesis 2(B) or null hypothesis three.

Table 15.
Hypotheses Testing: One, Two, and Three

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Null / Alternate</th>
<th>Description</th>
<th>Accept</th>
<th>Do not Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis 1</td>
<td>H1(_0)</td>
<td>PWDST has no effect on Percent of Key Products Accessed during preflight planning.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H1(_a)</td>
<td>PWDST has a positive effect on Percent of Key Products Accessed during preflight planning.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H2A(_0)</td>
<td>PWDST has no effect on Preflight Subcategory Weather Phenomena Score.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothesis 2</td>
<td>H2A(_a)</td>
<td>PWDST has a positive effect on Preflight Subcategory Weather Phenomena Score.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H2B(_0)</td>
<td>PWDST has no effect on Preflight Subcategory Weather Trending score.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H2B(_a)</td>
<td>PWDST has a positive effect on Preflight Subcategory Weather Trending Score.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothesis 3</td>
<td>H3(_0)</td>
<td>PWDST has no effect on Preflight Risk Perception.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H3(_a)</td>
<td>PWDST has a positive effect on Preflight Risk Perception.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Next, a logistic regression was run to assess the degree to which the four preflight measures (Percent of Key Products Accessed, Preflight Weather phenomena, Preflight Weather trending, and Preflight Risk) predicted Preflight Decision Making. This was used to test Hypothesis seven.

Tables 16 and 17 display the intercorrelations and descriptive statistics.

*Table 16.*

Correlations for Preflight Variables including Go or No-Go Decision

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preflight Weather Phenomena</td>
<td>78</td>
<td>85.58</td>
<td>18.91</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preflight Weather Trend</td>
<td>78</td>
<td>49.15</td>
<td>39.28</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Preflight Risk</td>
<td>78</td>
<td>35.47</td>
<td>40.68</td>
<td>0.10</td>
<td>0.55**</td>
<td></td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Preflight Percent of Key Percent Products Accessed</td>
<td>78</td>
<td>58.62</td>
<td>39.95</td>
<td>0.26*</td>
<td>0.22*</td>
<td>0.27*</td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Go or No Go decision a</td>
<td>78</td>
<td>0.47</td>
<td>0.50</td>
<td>0.071</td>
<td>-0.31**</td>
<td>-0.64**</td>
<td></td>
<td>-0.18</td>
</tr>
</tbody>
</table>

*0 = No Go and 1 = Go  *p < .05  **p < .01

*Table 17.*

Descriptive Statistics & T-Test results for Preflight including Go or No-go Decision

<table>
<thead>
<tr>
<th>Variable</th>
<th>Not Going VFR Flight Plan</th>
<th>Going On VFR Flight Plan</th>
<th>t (138)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather Phenomena</td>
<td>83.98</td>
<td>86.68</td>
<td>-0.62</td>
<td>0.538</td>
</tr>
<tr>
<td>Weather Trend</td>
<td>63.54</td>
<td>39.13</td>
<td>2.82</td>
<td>0.006</td>
</tr>
<tr>
<td>Risk</td>
<td>66.67</td>
<td>13.77</td>
<td>6.87</td>
<td>0.000</td>
</tr>
<tr>
<td>Percent of Key Products</td>
<td>67.05</td>
<td>52.77</td>
<td>1.57</td>
<td>0.121</td>
</tr>
</tbody>
</table>

The results of preliminary assumption testing was as follows:

- **Linearity.** Linearity of the continuous variables with respect to the logit of the dependent variable was assessed using the Box-Tidwell (1962) procedure. A Bonferroni correction
was applied, resulting in a more conservative alpha level, $p < .00625$ (Tabachnick & Fidell, 2014). Based on this assessment, all continuous independent variables were found to be linearly related to the logit of the dependent variable, except for Preflight Risk, $p < .00625$.

- **Multicollinearity & Singularity.** A Pearson's Correlation indicated there was no multicollinearity found amongst the dependent variables (see Table 16).

- **Outliers.** There were two standardized residuals with values of 3.613 and -3.023 standard deviations, these cases were kept in the analysis.

*Table 18.*

Logistic Regression Predicting Likelihood of Go or No Do on Preflight Performance Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>df</th>
<th>p</th>
<th>Odds Ratio</th>
<th>95% CI for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preflight Weather Phenomena</td>
<td>0.022</td>
<td>0.16</td>
<td>1.98</td>
<td>1</td>
<td>0.159</td>
<td>1.022</td>
<td>0.991 1.055</td>
</tr>
<tr>
<td>Preflight Weather Trend</td>
<td>0.003</td>
<td>0.009</td>
<td>0.117</td>
<td>1</td>
<td>0.732</td>
<td>1.003</td>
<td>0.985 1.022</td>
</tr>
<tr>
<td>Preflight Risk</td>
<td>-0.044</td>
<td>0.011</td>
<td>17.708</td>
<td>1</td>
<td>0.00</td>
<td>0.957</td>
<td>0.937 0.97</td>
</tr>
<tr>
<td>Percent of Key Products</td>
<td>-0.003</td>
<td>0.008</td>
<td>0.162</td>
<td>1</td>
<td>0.687</td>
<td>0.997</td>
<td>9.87 1.013</td>
</tr>
</tbody>
</table>

A direct logistic regression was performed to assess the impact of Percent of Key Products Accessed, Weather phenomena, Weather trending, and Risk on the likelihood that respondents would decide to embark on the prompted VFR flight plan or not. The full model containing all four predictors was statistically significant, $\chi^2 (4, N = 78) = 37.90$, $p = .000$, indicating that the model was able to distinguish between respondents who decided to embark on the prompted VFR flight plan or not. The model as a whole explained between 38.5% (Cox and Snell R square) and 51.9% (Nagelkerke R squared) of the variance in Preflight Decision Making,
and correctly classified 80.8% of cases. As shown in Table 18, “Preflight Risk” was the only variable that made a unique, statistically significant contribution to the model, recording an odds ratio of .96. This indicates that respondents who scored lower on Preflight Risk (i.e., perceived the flight as low risk regarding weather) were .96 times more likely to decide to embark on the prompted VFR flight plan, controlling for other factors in the model.

These results provide partial support of Hypothesis 7. We accept the alternate hypothesis for Preflight Risk, but do not reject the null Hypothesis 7 for Percent of Key Products Accessed, Preflight Weather Phenomena, or Preflight Weather Trending.

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Null / Alternate</th>
<th>Description</th>
<th>Accept</th>
<th>Do not Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>H7</td>
<td>H7_0</td>
<td>There is not a significant prediction of Decision Making by Percentage of crucial weather products accessed, Preflight Weather Phenomena, Preflight Weather Trending, and Preflight Risk.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H7_a</td>
<td>There is a significant prediction of Decision Making by Percentage of crucial weather products accessed, Preflight Weather Phenomena, Preflight Weather Trending, and Preflight Risk.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Inflight Hypotheses Analyses**

Next, a one-way, between groups MANOVA was run to investigate the experimental and control group differences on inflight performance variables (Hypotheses five and six). Three
dependent variables were included: Inflight Weather Phenomena, Inflight Weather Trending, and Total Time in IMC. The independent variable was the PWDST. The descriptive statistics and intercorrelation matrix for the inflight variables are shown in Table 20 and 21.

Table 20.
Correlations for Inflight Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Inflight Weather Phenomena</td>
<td>78</td>
<td>62.61</td>
<td>30.41</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Inflight Weather Trend</td>
<td>78</td>
<td>87.82</td>
<td>30.35</td>
<td>0.37**</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Inflight Total Time in IMC</td>
<td>78</td>
<td>285.64</td>
<td>447.1</td>
<td>0.10</td>
<td>0.32**</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>4 PWDST a</td>
<td>78</td>
<td>0.47</td>
<td>0.5</td>
<td>-0.113</td>
<td>0.001</td>
<td>-0.13</td>
<td>---</td>
</tr>
</tbody>
</table>

a 0 = Control Group (No PWDST) and 1= Experimental Group (PWDST). *p < .05 **p < .01

Table 21.
Descriptive Statistics Inflight Variables and Experimental Condition

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control Group</th>
<th>Experimental Group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 42</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Inflight Weather Phenomena</td>
<td></td>
<td>65.85</td>
<td>29.33</td>
</tr>
<tr>
<td>Inflight Weather Trend</td>
<td></td>
<td>87.8</td>
<td>31.19</td>
</tr>
<tr>
<td>Total Time in IMC</td>
<td></td>
<td>340.50</td>
<td>495.73</td>
</tr>
</tbody>
</table>

The results of preliminary assumption testing were as follows:

- **Outliers.** Boxplots and Mahalanobis Distances were conducted revealing 17 univariate outliers and no multivariate outliers. The univariate outliers were not removed for this analysis.
• **Normality.** A Shapiro-Wilk's test for normality indicated all dependent variables: Weather Phenomena, Weather Trending, and Total Time in IMC were not normally distributed for both levels of the independent variable, PWDST ($p < .05$).

• **Multicollinearity & Singularity.** A Pearson's Correlation indicated there was no multicollinearity found amongst the dependent variables (see table 20).

• **Linearity.** Scatterplots were developed to investigate linearity, results indicated there was no linear relationship between the DVs.

• **Homogeneity of Variance-Covariances.** A Box's test of equality of covariance matrices was conducted to evaluate homogeneity of variance-covariances matrices, the assumption of homogeneity of variance-covariances was satisfied ($p = .647$).

The omnibus multivariate test results indicated, there was not a statistical significant main effect of PWDST on the combined DVs, $F(3, 74) = .622$, $p = .603$; Pillai’s Trace = .025; partial $\eta^2 = .025$.
Table 22.

Hypotheses Testing: Five and Six

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Null / Alternate</th>
<th>Description</th>
<th>Accept</th>
<th>Do not Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>H5A₀</td>
<td></td>
<td>PWDST does not have an effect on Inflight Subcategory Weather Phenomena score.</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>H5Aₐ</td>
<td></td>
<td>PWDST has a positive effect on Inflight Subcategory Weather Phenomena Score.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H5B₀</td>
<td></td>
<td>PWDST does not have an effect on Inflight Subcategory Weather Trending Score.</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>H5Bₐ</td>
<td></td>
<td>PWDST has a positive effect on Inflight Subcategory Weather Trending Score.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H6₀</td>
<td></td>
<td>PWDST does not have an effect on Total Time in IMC.</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>H6ₐ</td>
<td></td>
<td>PWDST has a negative effect on Total Time in IMC.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Next, a multiple regression was used to assess the ability of three measures (Inflight Weather phenomena, Inflight Weather trending, and Inflight Weather Change) to predict Total Time in IMC, assessing Inflight performance (hypothesis nine). Tables 23 and 24 display the intercorrelations, descriptive statistics, and regression results.

Table 23.

Intercorrelations for Inflight Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Inflight Weather Phenomena</td>
<td>78</td>
<td>62.61</td>
<td>30.41</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2  Inflight Weather Trend</td>
<td>78</td>
<td>87.82</td>
<td>30.35</td>
<td>0.37**</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3  Inflight Weather Change a</td>
<td>78</td>
<td>0.69</td>
<td>0.46</td>
<td>0.11</td>
<td>0.03</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>
The results of preliminary assumption testing were as follows:

- **Independence of Observations.** The Durbin-Watson statistic was calculated to assess independence of residuals, results indicated there was not an independence of residuals, $d_w = .617$.

- **Linearity.** Partial regression plots and a plot of studentized residuals against the predicted values were developed to ensure approximate linearity.

- **Homoscedasticity.** Visual inspection of a plot of studentized residuals versus unstandardized predicted values, indicated the assumption of homoscedasticity was violated.

- **Multicollinearity.** Tolerance values were assessed and the assumption of multicollinearity was satisfied, since both tolerance values greater than 0.1.

- **Outliers, High leverage points, and Highly influential points.** There were no studentized deleted residuals greater than $\pm 3$ standard deviations, no leverage values greater than 0.2, and values for Cook's distance above 1.

- **Normality.** A Q-Q Plot was generated to assess the assumption of normality, this assumption was violated.

A standard multiple regression was used to assess the ability of three measures (Inflight Weather trending, Inflight Weather Phenomena, and Inflight Weather Change,) to predict Total Time in IMC. The multiple regression model significantly predicted Total Time in IMC, the total variance explained by the model as a whole was 10.0%, $F(3, 74) = 2.729, p = .05$. Only Inflight
Weather Phenomena was statistically significant (beta = 4.72, p = .008). Regression coefficients and standard errors can be found in Table 24 (below).

Table 24.
Regression Analysis Summary for Inflight Performance Variables Predicting Inflight Decision Making

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflight Weather Phenomena</td>
<td>4.72</td>
<td>1.74</td>
<td>0.32</td>
<td>1</td>
<td>0.008</td>
</tr>
<tr>
<td>Inflight Weather Trend</td>
<td>-0.30</td>
<td>1.78</td>
<td>-0.02</td>
<td>1</td>
<td>0.866</td>
</tr>
<tr>
<td>Inflight Weather Change</td>
<td>16.92</td>
<td>108.18</td>
<td>0.02</td>
<td>1</td>
<td>0.88</td>
</tr>
</tbody>
</table>

These results provide partial support of Hypothesis 8, and we accept the alternate hypothesis for the variable Inflight Weather Phenomena, but we do not reject the null Hypothesis 8 for the variables Inflight Weather Trending or Inflight Weather Change.

Table 25.
Hypotheses Testing: Eight

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Null / Alternate</th>
<th>Description</th>
<th>Accept</th>
<th>Do not Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>H8</td>
<td>H8o</td>
<td>There is not a significant prediction of Time Flown into IMC by Inflight Weather Phenomena, Inflight Weather Trending, Inflight Weather Change.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H8a</td>
<td>There is a significant prediction of Time Flown into IMC by Inflight Weather Phenomena, Inflight Weather Trending, Inflight Weather Change.</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

A series of regression analyses (Hayes, 2013) was used to investigate the hypothesis that Preflight Risk mediates the effect of PWDST on Time Flown Intro IMC. The total effect of the manipulation on Time Spent in IMC was significant c = -279.785, t(121) = -3.0492 p = 0.0033.
With 95% confidence, Tc resides somewhere between -462.834 and -96.736. The direct effect is also statistically different from zero, c’ = -273.931, t(120) = -2.840 p = .0060. The null hypothesis that T c’ = 0 can be rejected. The interval estimate for T c’ is -466.441 to -81.422 with 95% confidence. However, indirect effect was tested using bootstrapping procedures (Hayes, 2013) with 5,000 bootstrapped samples. The bootstrapped 95% confidence interval ranged from -76.1089 to 52.8233. Thus, the indirect effect was not statistically significant and mediation did not have an effect.

![Diagram](image.png)

**Figure 12.** Preflight Risk as a mediator between the effect of PWDST on Time Flown Intro IMC

These results do not support Hypothesis 9, and we do not reject the null hypothesis 9.
Table 26.

Hypotheses Testing: Ten

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Null / Alternate</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H9</td>
<td>H9₀</td>
<td>The impact of PWDST on Time Flown Into IMC is not effected by Preflight risk.</td>
</tr>
<tr>
<td>H₉</td>
<td>H₉ₐ</td>
<td>There is a significant prediction of Time Flown into IMC by, Weather Phenomena, Weather Trending, Weather Change.</td>
</tr>
</tbody>
</table>

Exploratory Analyses

The analyses reported in this section were not included in the original set of analyses. These analyses were conducted to further investigate possible effects, relationships, hypotheses, and results.

Investigation of Preflight and Inflight Performance Variable Relationships. In order to understand preflight and inflight variable relationships an intercorrelation matrix was conducted. Results indicated very small insignificant relationships between Inflight and Preflight Variables (see Table 27).
Table 27. Correlations for Preflight and Inflight Performance Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preflight Weather Phenomena</td>
<td>78</td>
<td>85.58</td>
<td>18.91</td>
<td>---</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Preflight Weather Trend</td>
<td>78</td>
<td>49.15</td>
<td>39.28</td>
<td>0.18</td>
<td>---</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Preflight Risk</td>
<td>78</td>
<td>35.47</td>
<td>40.68</td>
<td>0.10</td>
<td>0.55*</td>
<td>---</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Preflight Percent of Key</td>
<td>78</td>
<td>58.62</td>
<td>39.95</td>
<td>0.26*</td>
<td>0.22*</td>
<td>0.27*</td>
<td>---</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PWDST</td>
<td>78</td>
<td>0.47</td>
<td>0.50</td>
<td>0.30**</td>
<td>0.20</td>
<td>0.27*</td>
<td>0.91**</td>
<td>---</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Preflight Go or No GO on VFR</td>
<td>78</td>
<td>0.59</td>
<td>0.50</td>
<td>0.07</td>
<td>-</td>
<td>0.31**</td>
<td>-</td>
<td>0.64**</td>
<td>-</td>
<td>0.18</td>
<td>-</td>
<td>0.20</td>
<td>-</td>
</tr>
<tr>
<td>Inflight Weather Phenomena</td>
<td>78</td>
<td>62.61</td>
<td>30.41</td>
<td>-</td>
<td>0.15</td>
<td>-</td>
<td>0.01</td>
<td>0.03</td>
<td>-</td>
<td>0.13</td>
<td>-</td>
<td>0.27</td>
<td>-</td>
</tr>
<tr>
<td>Inflight Weather Trend</td>
<td>78</td>
<td>87.82</td>
<td>30.35</td>
<td>-</td>
<td>0.18</td>
<td>0.14</td>
<td>0.02</td>
<td>0.03</td>
<td>0.00</td>
<td>-</td>
<td>0.03</td>
<td>0.37**</td>
<td>-</td>
</tr>
<tr>
<td>Inflight Weather Change</td>
<td>78</td>
<td>0.69</td>
<td>0.46</td>
<td>0.08</td>
<td>0.08</td>
<td>-</td>
<td>0.06</td>
<td>-</td>
<td>0.06</td>
<td>-</td>
<td>0.05</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>Inflight Total Time in IMC</td>
<td>78</td>
<td>28.36</td>
<td>44.714</td>
<td>-</td>
<td>0.14</td>
<td>-</td>
<td>0.22</td>
<td>-</td>
<td>0.10</td>
<td>-</td>
<td>0.13</td>
<td>-</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Weather Change and 1 = Report PIREP at Weather Change.

a Control Group (No PWDST) and 1 = Experimental Group (PWDST).
b 0 = No Go and 1 = Go.
c 0 = Did Not Report PIREP at Weather Change and 1 = Report PIREP at Weather Change.
Retest of Hypotheses Four. Initially, the Preflight MANOVA was intended to assess the effect of the PWDST on all preflight measures (Preflight Percent of Key Products Accessed, Preflight Weather Phenomena, Preflight Weather Trending, Preflight Risk, and Preflight Decision Making). However, during data processing, the preflight decision-making construct resulted in dichotomous data (GO or No Go decision) instead of a continuous variable. Therefore, the decision-making variable was unable to be included in the MANOVA analysis, and instead the difference in conditions groups responses in Preflight Decision Making (GO or No GO) was assessed using the Test of Two Proportions (i.e., a chi-square analysis).

The results of preliminary assumption testing was as follows:

- **Dichotomous Variables: One Independent Variable and One Dependent Variable.**
  
  This assumption was satisfied.

- **Independence of Observations.** The assumption of independence of observations was satisfied.

- **Randomly Assigned Groups.** The assumption of randomly assigned groups was satisfied.

- **Sample Size.** The minimum expected frequency in any of the cells is 15.20, which is greater than 5. Therefore, the assumption of adequate sample size was satisfied.

The test of two proportions used was the chi-square test of homogeneity in order to compare differences in proportions for the PWDST condition (control group and experimental group) and preflight Decision Making (Go or No Go). Results indicated that 19 (51.4%) participants in the experimental group decided not to Go on the proposed VFR flight plan compared to 13 (31.7%)
participants in the control group (34%), indicating a difference in proportions of .19, that is not significant $p = .078$ (see Table 28).

*Table 28.*
Preflight Test of Proportions Results

<table>
<thead>
<tr>
<th>Condition</th>
<th>Go or No Go Decision</th>
<th>No</th>
<th>Percent</th>
<th>Yes</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td></td>
<td>13</td>
<td>31.70%</td>
<td>28</td>
<td>68.30%</td>
</tr>
<tr>
<td>Experimental Group</td>
<td></td>
<td>19</td>
<td>51.40%</td>
<td>18</td>
<td>48.60%</td>
</tr>
</tbody>
</table>

As a result, there is no support of the preflight hypothesis 4 and we do not reject the null hypothesis (see Table 29).

*Table 29.*
Hypothesis Testing: Four

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Null / Alternate</th>
<th>Description</th>
<th>Accept</th>
<th>Do not Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis 4</td>
<td>H4₀</td>
<td>Participants in the experimental group will not differ in their decision to Go or Not Go</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>H4ₐ</td>
<td>More participants in the experimental group will Decide to Not Go than participants in the control group</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Additional Analyses Investigating Decision Making.* Results of the Test of Two Proportions revealed there was not a significant difference between Condition groups’ decision to fly. However, previous research indicates that decision-making may be affected by various factors other than weather and flight information, such as, social biases, risk tolerance, and the ability to plan an alternate airport and route changes. Another inspection of participant responses
revealed that the majority of experimental group participants reported, planning an alternate or planning to turn around as a reason for deciding to fly to fly the proposed VFR flight plan.

Next, to gain more insight on participant responses regarding prefight decision-making, another Test of Two Proportions was run to assess group differences in the response to the following statement on the Post Preflight Survey, “Based on the provided information this flight should be safe to fly VFR and land at the proposed destination airport.”

The results of preliminary assumption testing was as follows:

- **Dichotomous Variables: One Independent Variable and One Dependent Variable.**
  This assumption was satisfied.

- **Independence of Observations.** The assumption of independence of observations was satisfied.

- **Randomly Assigned Groups.** The assumption of randomly assigned groups was satisfied.

- **Sample Size.** The minimum expected frequency in any of the cells is 13.10, which is greater than 5. Therefore, the assumption of adequate sample size was satisfied.

The test of two proportions used was the chi-square test of homogeneity in order to compare differences in proportions for the PWDST condition (control group and experimental group) on responses to whether the VFR flight plan was safe for the flight to the destination airport. Results indicated that 17 (45.90%) participants in the experimental group disagreed that the flight was safe to fly VFR and land at the destination airport compared to eight (19.50%) participants in the control group. This was a statistically significant difference in proportions of .26, \( p = .012 \).
The next analysis assessed the difference in condition groups’ responses to the following statement on the Post Preflight Survey, “This flight could be risky due to weather conditions.”

Table 30.
Preflight Decision Making Test of Proportions Results: Whether it is Safe To Fly VFR Flight

<table>
<thead>
<tr>
<th>Condition</th>
<th>Safe To Fly VFR Flight</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incorrect</td>
<td>Percent</td>
<td>Correct</td>
</tr>
<tr>
<td>Control Group</td>
<td>33</td>
<td>80.50%</td>
<td>8</td>
</tr>
<tr>
<td>Experimental Group</td>
<td>20</td>
<td>54.10%</td>
<td>17</td>
</tr>
</tbody>
</table>

The results of preliminary assumption testing was as follows:

- **Dichotomous Variables: One Independent Variable and One Dependent Variable.**
  This assumption was satisfied.

- **Independence of Observations.** The assumption of independence of observations was satisfied.

- **Randomly Assigned Groups.** The assumption of randomly assigned groups was satisfied.

- **Sample Size.** The minimum expected frequency in any of the cells is 12.60, which is greater than 5. Therefore, the assumption of adequate sample size was satisfied.

To compare differences for condition (control group and experimental group) on responses on another item on the Preflight Decision Making Test, “Riskiness of Flight Due to Weather”, another test of two proportions (the chi-square test of homogeneity) was used. Results indicated that 18 (48.60%) participants in the experimental group agreed that the flight the flight could be risky due to weather conditions, compared to six (14.60%) participants in the control group. This was a statistically significant difference in proportions of .34, $p = .001$ (See Table 31).
Table 31.

Preflight Decision Making Test of Proportions Results: Riskiness of Flight Due to Weather

<table>
<thead>
<tr>
<th>Condition</th>
<th>Riskiness of Flight Due to Weather</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incorrect</td>
<td>Count</td>
<td>Percent</td>
</tr>
<tr>
<td>Control Group</td>
<td>35</td>
<td>85.40%</td>
<td></td>
</tr>
<tr>
<td>Experimental Group</td>
<td>19</td>
<td>51.40%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Correct</td>
<td>6</td>
<td>14.60%</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>48.60%</td>
<td></td>
</tr>
</tbody>
</table>

Retest of Hypotheses Five, Six, and Seven. The initial/hypothesized Inflight MANOVA was intended to assess the effect of the PWDST on all Inflight measures (Inflight Weather Phenomena, Inflight Weather Trending, Inflight Risk, and Total Time in IMC). However, the data failed the majority of assumptions for the MANOVA analysis, and thus, these results were somewhat inconclusive. Therefore, as additional exploratory analyses, the differences between conditions on each inflight dependent variable were examined using a series of T-tests. For these T-tests, an adjusted alpha level of 0.0167 was necessary in order to avoid type 1 errors.

PWDST Effect on Inflight Weather Phenomena

An Independent Samples T-test was run to assess the difference between condition group responses on Inflight Weather Phenomena.

The results of preliminary assumption testing were as follows:

- **Outliers.** Boxplots developed and revealed there were no outliers.
- **Normality.** A Shapiro-Wilk's test for normality indicated Inflight Weather Phenomena was not normally distributed for both levels of the independent variable, PWDST ($p < .05$).
• **Homogeneity of Variance-Covariances.** Levene’s test for equality of covariance matrices was conducted to evaluate homogeneity of variances, the assumption of homogeneity of variances was satisfied ($p = .685$).

An independent-samples t-test was conducted to compare the Inflight Weather Phenomena scores for the experimental and control group. There was no significant difference in scores for the control group (M = 65.85, SD = 29.33) and the experimental group (M = 59.01, SD = 31.57; $t (76) = .099, p = .324$, two-tailed). The magnitude of the differences in the means (mean difference = 6.84, 95% CI: –6.89 to 20.58) was very small (eta squared = .224).

*Table 32.*

PWDST on Inflight Weather Phenomena T-Test Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 41</th>
<th>Experimental n = 37</th>
<th>$t(76)$</th>
<th>$p$</th>
<th>Cohen's $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflight Weather Phenomena</td>
<td>M = 65.85, SD = 29.33</td>
<td>M = 59.01, SD = 31.57</td>
<td>0.99</td>
<td>0.324</td>
<td>0.224</td>
</tr>
</tbody>
</table>

PWDST Effect on Inflight Weather Trending

A Independent Samples T-test was run to assess the difference between condition group responses on Inflight Weather Trending.

- **Outliers.** Boxplots developed and revealed there were 10 outliers, all outliers were removed.

- **Normality.** A Shapiro-Wilk's test for normality indicated Inflight Weather Trending was not normally distributed for both levels of the independent variable, PWDST ($p < .05$).
- **Homogeneity of Variance-Covariances.** Levene’s test for equality of covariance matrices was conducted to evaluate homogeneity of variances, the assumption of homogeneity of variances was satisfied ($p = .868$).

An independent-samples t-test was conducted to compare the Inflight Weather Trending scores for the experimental and control group. There was no significant difference in scores for the control group ($M = 97.22$, $SD = 16.67$) and the experimental group ($M = 96.88$, $SD = 17.68$; $t(66) = .083$, $p = .934$, two-tailed). The magnitude of the differences in the means (mean difference = .35, 95% CI: –7.97 to 8.67) was very small (eta squared = .002).

Table 33.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control n = 36</th>
<th>Experimental n = 32</th>
<th>t(66)</th>
<th>p</th>
<th>Cohen's $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflight Weather Trend</td>
<td>97.22, 16.67</td>
<td>96.88, 17.68</td>
<td>0.08</td>
<td>0.93</td>
<td>0.002</td>
</tr>
</tbody>
</table>

PWDST Effect on Total Time in IMC

An Independent Samples T-test was run to assess the difference between condition group responses on Total Time in IMC.

- **Outliers.** Boxplots developed and revealed there were 7 outliers, all outliers were removed.

- **Normality.** A Shapiro-Wilk's test for normality indicated Inflight Weather Trending was not normally distributed for both levels of the independent variable, PWDST ($p < .05$).
• **Homogeneity of Variance-Covariances.** Levene’s test for equality of covariance matrices was conducted to evaluate homogeneity of variances, the assumption of homogeneity of variances was violated \((p = .000)\).

Since the assumption of homogeneity of variances was violated, a Welch’s t-test was conducted to compare the Total Time in IMC scores for the experimental and control group. Results indicate, there was statistically significant difference in scores for the control group \((M = 340.50, \ SD = 495.73)\) and the experimental group \((M = 60.71, \ SD = 89.83; \ t(69) = 3.05, \ p = .001, \ two\text{-}tailed)\). The magnitude of the differences in the means \(\text{mean difference} = 279.79, 95\% \ CI: 120.25 \text{ to } 439.32\) was medium size effect \(\text{eta squared} = .785\).

*Table 34.*

PWDST on Total Time in IMC T-Test Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n = 41)</th>
<th>Experimental (n = 30)</th>
<th>(t(69))</th>
<th>(p)</th>
<th>Cohen's (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflight Weather Phenomena</td>
<td>M = 340.5, SD = 495.73</td>
<td>M = 60.71, SD = 89.83</td>
<td>3.05</td>
<td>0.001</td>
<td>0.785</td>
</tr>
</tbody>
</table>
The PWDST was designed to assist pilots with accessing, interpreting and applying weather products during weather preflight planning. Therefore, Hypotheses One, Two, and Three proposed that the PWDST would increase information acquisition (i.e., the number of key weather products pilots accessed during preflight weather planning) (H1) and, in turn, how accurately participants were able to report weather phenomena (H2A), weather trending (H2B), and overall weather risk for the proposed flight route (H3). These predictions were based on previous research citing preflight weather planning as a critical component in the development of pilots’ mental model of developing and present weather along their flight route (Lanicci et al., 2012), as well as the efficacy of performance support tools in other domains (Barness,
These hypotheses were partially supported. Results indicated that the PWDST had a significant effect on the percentage of key weather products that the pilots accessed during preflight, as well as how accurately participants were able to report the forecasted weather phenomena for their flight route. Although results indicated there was only a small correlation between percent of key products accessed and preflight weather phenomena, these results support previous research suggesting that the perceive (information acquisition), process (information assessment), and preform (information application) stages of preflight are sequential steps that are dependent upon each other (Parson et al., 2005). Participants in the PWDST condition received guidance from the performance support tool, on: 1) how to access all key products on the Aviation Weather Website, and 2) a review of each products’ purpose and limitations. (King, Blickensderfer, & Chaparro, 2019 (ref this HFES paper)). In turn, this
performance support led to an increase in the percentage of key products accessed by participants in the PWDST condition. Previous research indicates that gathering a variety of weather products can assist with building a more well-rounded mental model of present and developing weather (Vincent et al., 2013). Therefore, it is not surprising that pilots who used the PWDST and accessed more key weather products, also reported weather phenomena more accurately than participants in the control condition.

Hypothesis four proposed that more participants who used the PWDST (experimental group) would decide NOT to embark on the VFR flight plan, compared to participants who did not use the PWDST (control group). This hypothesis was developed based on previous research that suggests that when making decisions, operators depend on their long term memory, short term memory and stimuli to influence their choices and actions (Wickens, Gordon, Liu, & Lee, 1998). During the perceive stage of the weather preflight process, pilots gather weather information and must fully process that information in order to gain a robust mental model of developing weather and, in turn, assist with decision-making (Parson et al., 2005). Decisions using weather mental models include route changes and, ultimately, the final decision of whether to embark on the flight plan or not.

For the experimental task, participants were required to perform their preflight planning for a proposed VFR flight plan and ultimately decide, based on the information they gathered, whether they should embark on the VFR flight plan or not (Go or No Go decision). (Note that the participants in this study were all non-instrument rated VFR Private Pilots, which means that regulations (FAA, 2020), prohibit them from flying into IMC.) Hence, hypothesis four predicted that pilots using the PWDST (experimental group) would have a more clear understanding of the forecasted weather, and decide NOT to embark on the VFR flight as
compared to participants who did not use the PWDST (control group). This hypothesis was not
supported. Results indicated that there was not a significant difference between experimental
conditions and their decision to Go or Not Go. These results may seem odd, considering that the
participants who used the PWDST: 1) accessed more key weather products and 2) seemed to
have a better understanding of present and developing weather. Multiple factors exist, however,
that could have contributed to the lack of significance in the go-no go decision.

The factors include that, first, participants may have decided to fly the proposed VFR
flight plan with plans to divert to an alternate airport, if the weather deteriorated. Second,
participants may have felt social pressure to continue with the flight since they were getting paid
to complete the entire research study. Lastly, participants may have felt the flight would be less
of a risk since it is a simulated flight scenario.

**Exploratory Results**

*Retest of Hypothesis Four.* Exploratory analyses, revealed that numerous participants in
the experimental group who made the decision to fly the VFR flight (i.e., decision to Go) also
stated “planning an alternate airport” as a reason as to why they decided to fly the proposed
VFR flight plan. This inspection of the raw data, led to subsequent analyses which revealed that,
despite a lack of significant difference between condition groups on the Go/No-Go decision.
there was a significant difference between groups when responding whether the VFR flight plan
was safe to fly as originally planned. More participants in the PWDST condition disagreed with
the statement that it was safe to fly the proposed VFR flight plan and land at the destination
airport, than participants in the control group. Additionally, when comparing responses between
conditions on how much they agree with whether this flight is risky due to weather, there was a
significant difference between group responses. More participants in the PWDST condition
agreed that the flight was risky due to weather compared to participants in the control group. These findings support previous research that indicates there are many factors at play when deciding to embark on a flight plan and include biases, social pressure, as well as flexibility of changing a flight plan, can be crucial components in preflight decision-making (NTSB, 2005).

**Preflight Performance Variables Ability to Predict Preflight Decision Making**

*Hypothesized Results*

Hypothesis Seven proposed that, aside from the PWDST itself, the preflight performance variables (i.e., Percent of Key Products Accessed, Preflight Weather Phenomena, Preflight Weather Trending, and Preflight Risk) would predict whether participants decided to embark on the proposed VFR flight plan or not (see Figure 15).

*Figure 15. Preflight Performance Variables Predict Go No Go Decision (Hypothesis 7)*
This hypothesis was developed based on previous research that suggests deciding whether to embark on a flight plan depends on multiple factors, and previous research indicates that information acquisition and analysis are key components in decision-making (Patel & Groen, 1991; Wiggins & O'Hare, 1995). Additionally, while decision-making biases may be a contributing factor for VFR into IMC incidents, other decision errors may be a result of poor preflight planning, limited aviation weather knowledge and skills, and in general, a lack of understanding of the existing and forecasted weather and its implication for flight (Blickensderfer et al., 2017; FAA, 2010; Fultz & Ashley, 2006). Therefore, it was hypothesized that preflight performance variables, such as Percent of Key Products Accessed, Preflight Weather Phenomena, Preflight Weather Trending, and Preflight Risk would predict whether participants decided to embark on the proposed VFR flight plan or not. This hypothesis was partially supported. Although the logistic regression model was statistically significant, results indicated only Preflight Risk uniquely contributed to the model. These results are unexpected, considering the literature supports that information gathered in the preflight process should guide preflight decision-making (NTSB, 2005). These results do not align with previous research that suggests that operators’ information selection could depict expertise and can be informative when assessing pilots’ decision-making in the preflight phase, where weather information is acquired and route and inflight decisions are determined (Wiggins, 2014). Further investigation into the data revealed these results could be due to the various limitations associated with this analysis, such as, limitations of the measures, a lack of linearity between the independent variables and the dependent variable and the two outliers left in the analysis.

**PWDST Effect on Inflight Performance**
Hypothesized Results

Hypotheses Five and Six proposed that using the PWDST during preflight would have a positive effect on inflight performance including: Inflight Weather Phenomena (H5), Inflight Weather trending (H5B), and Total Time in IMC (H6) (see Figure 16).

Figure 16. Effect of PWDST on Inflight Performance Hypotheses

Again, these hypotheses were based on several areas of the literature. First, previous research which indicates that pilots rely on long term memory, feature cue association, and personal skills / abilities in order to assess situational awareness and risk perception while inflight (Wiggins, 2014; Hunter, 2002). At the same time, previous research suggests that intermediate skill level operators have not fully established efficient expert level qualitative information processing which is necessary to process task related information and implement action effectively (Bell, 1997). Thus, if pilots lack knowledge of aviation weather principles, it could hinder their ability to use cue utilization (external environmental cues and gathered information) and long term
memory to assess their situation (Wiggins & O’Hare, 2003). Which in turn, can determine the quality of weather phenomena assessment and decision-making while inflight. One strategy to help operators perform in these situations is to use a performance support tool. Prior research on performance support tools has provided evidence that such tools do improve performance in a variety of fields (Barness, Tunnessen, Worely, Simmons, & Ringe, 1974; Miller, Chanllinor, Masarie, & Myers, 1986). Hence, it was hypothesized that using a performance support tool would improve pilots understanding of weather inflight. However, results indicated, the effect of PWDST on inflight performance was not significant. These findings are not aligned with the literature, which led to further investigation of these results.

**Exploratory Results**

*Additional tests of Hypothesis Five and Six.* Exploratory analyses investigated the effect of PWDST on each dependent variable separately and with all outliers removed. Results indicated, the PWDST did not have a significant effect on Inflight Weather Phenomena (H5) and Inflight Weather trending (H5B). However, the PWDST did have a significant effect on Total time in IMC (H6). The lack of effect of PWDST on Inflight Weather phenomena and Inflight Weather trending, could be due to the lack of construct validity and/or sensitivity of the measures. These measures were developed for this dissertation and had not been used in prior research. In contrast to the Inflight survey measures, the total time pilots fly into IMC has been used successfully in previous studies as a measure for inflight performance (Johnson & Wiegmann, 2015).

The current results about IMC are similar to findings in previous research that investigated interventions to aid pilots in avoiding inflight weather hazards. For example, Alhstrom (et al?) (2016) found that participants who had access to portable weather technology maintained a greater horizontal distance from degraded weather conditions (i.e., away from IMC) than
participants in the control group. Other research indicated that pilots who received training on weather cue interpretation tended to deviate earlier when encountering hazardous weather conditions (Wiggins & O’Hare, 2003). In the current study, participants who used the PWDST received guidance on each weather product and guidance on risk that provided some level of warning about the effect of present weather conditions on flight. As a result, pilots that used the PWDST not only accessed a greater percentage key weather products, and had a better understanding of current weather conditions before flight, they also spent less time in IMC conditions.

**Inflight Performance Variables Ability to Predict Total Time in IMC**

**Hypothesized Results**

Hypothesis Eight proposed that, PWDST aside, participant scores on Inflight Weather Phenomena, Inflight Weather Trend, and Inflight Weather Change would successfully predict pilots’ total flight time in IMC (see Figure 17)
Figure 17. Inflight Performance Variables Predict Total Time in IMC (Hypothesis 8)

Again, this was hypothesized based on previous research that suggests that situational assessment and feature cue association are essential for avoiding degraded weather conditions inflight (Wiggins & O’Hare, 2003). Thus, pilots who have more accurate understanding of the inflight weather conditions were expected to have shorter times (if any) in IMC. Pilots may encounter IMC as a result of an inadequate situation assessment of current and developing weather and the potential effects on flight. Although, results indicated the model was statistically significant, only Inflight Weather Phenomena was a statistically significant contributor to the model. Inflight Weather Trend and Inflight Weather Change did not significantly contribute to the prediction of Total Time In IMC. Therefore, Hypothesis 8 is partially supported. These findings contradict theories in the literature claiming that weather inflight assessment and cue utilization are essential for IMC avoidance.
Several explanations exist as to why scores on weather trending and weather changes did not predict time in IMC. First, the measures had not been used in prior research and, thus, the construct validity may have been suspect. Additionally, the new measures may not have been fully sensitive to detect differing levels of understanding. Finally, several statistical assumptions were violated for this analysis, including Homoscedasticity, Independence of Residuals, and Normality of the data. These violations could have impacted the reliability and validity of our results.

Preflight and Inflight Performance Variables Relationships

Hypothesized Results

Hypothesis Nine proposed that Preflight risk mediates the relationship between the PWDST and Total Time in IMC (see Figure 18). This was hypothesized due to previous research that suggests inadequate preflight planning, poor decision-making, poor situational awareness, and inadequate risk assessment as key contributors to unintentional VFR into IMC (National Transportation Safety Board, 2005). Prior research findings highlight how much preflight planning provides a foundation for inflight performance and situational awareness. Based on the argument for (but few empirical findings of), the impact of preflight weather planning on inflight performance, the current study investigated the relationship between preflight and inflight variables.
Results indicated that no correlations between inflight and preflight variables existed. These results were not consistent with arguments on the importance of weather preflight in the general aviation guidance literature (FAA, 2008; FAA, 2019). Further investigation into the relationship between Preflight Risk, Total Time in IMC, and the PWDST indicated, there was a significant direct relationship and a significant total effect of PWDST and on Total Time in IMC. However, the indirect effect of PWDST on Preflight Risk and Preflight Risk on Total Time in IMC was not significant. Therefore, Hypothesis nine was not supported. Although these findings do not reflect arguments in the literature, the results are not surprising, considering the lack of correlation between Preflight and Inflight variables.

Key Findings

To summarize, the purpose of this study is to investigate the effect of a performance support tool (PWDST) for weather preflight on pilots’ preflight performance and inflight performance. Results indicated that participants in the PWDST condition displayed better Preflight
performance than the control condition, specifically, a higher rate of Information acquisition (Percent of Key Products Accessed) and higher reported Weather awareness (Preflight Weather Phenomena). While there was no significant effect of the PWDST on the Go or No Go decision, further investigation did reveal PWDST had a significant effect on participants Preflight decision-making. More participants in the PWDST condition decided the flight was not safe to fly as planned without any flight plan changes and also reported the flight was risky due to weather. Additionally, Preflight performance variables did predict Preflight decision-making (Go or No Go decision), with Risk perception (Preflight Risk) uniquely contributing to the logistical model. Furthermore, when investigating the PWDST effect on Inflight performance, results revealed participants in the PWDST condition spent less time in IMC (Total Time in IMC) than participants in the control condition. However, there were no differences between conditions in Inflight Weather Awareness (Inflight Weather Phenomena and Inflight Weather Trending). At the same time, results did reveal the Inflight Weather Awareness (Inflight Weather Phenomena, Inflight Weather Trending, Weather Change) was able to successfully predict Inflight Decision Making (Total Time in IMC), with Inflight Weather Phenomena significantly contributing to the model. Lastly, although supported in the literature, study results revealed very little support for the relationship between preflight and inflight performance.

**Limitations**

There are several factors that may limit the findings and generalizability of this study. The sample for this study was limited and may not be representative of the overall General aviation community. Although participants were being compensated to complete the study and were instructed to treat this scenario as a they would a real flight, it is possible participants may
have taken more risks due to the scenario being simulated. The study was also approximately five hours long, and fatigue could have impacted participant’s performance.

**External Validity.** Every effort was taken to try to increase and maintain the external validity of this study. The experimental task including simulated preflight weather planning and simulated inflight scenario. For both scenarios pilots were provided with the same materials they would have access to in real life, and when this was unavailable our team created very similar mock materials. These materials were developed by a multidisciplinary team of meteorologists, human factors specialists, and pilots of varying levels of experience. Weather data used for the Inflight scenarios was based on actual historic weather data, very few features were edited for simulation fidelity. Some limitations include the fidelity of the graphical depiction of weather in the Prepare3D software and it’s limitations on user depth perception. As well as, the altering of historical weather data in order to provide a more gradual VFR into IMC transition. There were also times where there were some technical difficulty with the PWDST and participants had to re-enter their information into the app.

**Construct Validity.** Although all the measures were developed with a multidisciplinary team, it is very difficult to measure accuracy on weather phenomena, trending, and weather risk perception. This has been cited as an issue in previous research and there are limited validated measures available for these constructs (Weiss & Shanteau, 2003). During data processing each survey measures was assessed for reliability and as a result certain questions were removed to ensure reliability and this could have affected the overall construct validity of these measures.

**Statistical Validity.** There are some issues regarding the statistical validity of this study. This study is slightly underpowered, with the optimum sample size being around 85 participants. Additionally, assumptions were violated for certain analyses, which could effect the validity of
these results. However, retesting with more appropriate analyses and tests were used in exploratory analyses to further investigate these findings. Assumption for the majority of the exploratory analyses were satisfied.

**Theoretical and Practical Implications**

The findings in this study provide implications for the GA Weather community and our approach towards novice pilots’ lack of knowledge and skills, by investigating the effect of automated guided assistance throughout the preflight process (e.g. a performance support tool, PWDST) on preflight and inflight performance. Previous research indicates Private pilots account for the majority of GA weather-related accidents and VFR into IMC (Fultz & Ashley, 2016). Previously cited contributing factors include weather knowledge and preflight planning (NTSB, 2005; Blickensderfer et al., 2017.; Burian & Jordan, 2002). The PWDST focuses on improving preflight planning, in efforts to improve novice private pilots’ mental models of developing weather and weather-related flight risks by assisting with weather information acquisition, analysis, and application; while providing risk assessment guidance. Previous research suggests that limitations associated with weather information acquisition include the accessibility of weather products, insufficient understanding of weather product limitations, and the low level of product interpretability (Blickensderfer et al., 2015; Lanicci et al., 2012). In the present study comparisons were made between groups provided with assistance in weather product accessibility, product limitation, and product interpretation. Unfortunately, there is no way of delineating exactly which aspect of the PWDST improved Information acquisition, preflight weather awareness, preflight and inflight decision-making. However, these results support previous research that suggests that sequential preflight stages, perceive, process, and perform, are building blocks for weather mental model development, preflight, and inflight
perceptions and decision-making (Lanicci et al., 2012; Parson et al., 2005). It begs the question, how much weather training and weather knowledge is needed for novice pilots to understand weather information and make informed decisions, or whether the scientific communities’ approach to this issue has been wrong? Previous studies have tended to focus on developing more dynamic and graphical weather displays in and out of the cockpit, as well as operator training. Previous research on the implementation of more graphical and dynamic weather displays tend to result in limited improvement in weather avoidance, instead, some of these tools were used to fly closer to hazardous weather (Burgess & Thomas, 2004). While other interventions, such as, weather training and portable weather devices resulted in increased weather situational awareness, although pilots still flew too close to degraded weather conditions (Wu, Gooding, Shelley, Duong, and Johnson, 2012; Ahlstrom et al., 2016). Few approaches have attempted to include interpretation guidance, risk guidance, as well as guidance on weather phenomena implications for flight. Perhaps, our approach should focus on increased product usability, accessibility, and guidance on information application, as well as risk. Although participants in the PWDST condition and Control condition only slightly varied in aviation weather knowledge, their differences in preflight performance and inflight decisions were significant. If this were a real life scenario, differences in performance between the PWDST condition and the control condition may have been a matter of life or death.

This study also offers implications for research methodology in GA Aviation weather research. Previous studies investigating the effects of interventions on inflight weather avoidance rarely include a high fidelity simulation of the preflight planning process. This is imperative in order to truly understand how introduced interventions impact inflight decision-making. As previously stated, the preflight planning process is where the mental model and initial
perspective of the flight plan are formed. Continuing to conduct studies simply investigating inflight performance as an isolated event is unrealistic and can hinder the generalizability of the study findings. Results from this study, support the importance of including high fidelity preflight scenarios along with inflight scenarios to truly capture participant behaviors and performance that may have significant impacts on inflight performance.

**Future Research**

Future research should continue to investigate the relationship between Preflight and Inflight performance. As previously noted, the literature suggests a causal relationship between Preflight and Inflight performance. However due to the lack of reliable measures for preflight weather planning, there has been difficulty supporting this relationship (Blickensderfer et al., 2017; Hunter, 2002; O’Hare, 1990; Weiss & Shanteau, 2003). There are very few validated risk perception, aviation weather awareness, and decision-making measures available for research to adapt and use for their specific simulated scenario. Advancements in validated measure development is a critical component to understanding the GA weather problem.

Further investigation should be invested in improving the quality of tools available to researchers to simulate preflight planning materials as well as, simulated depictions of weather and weather generation. A high fidelity simulated environment is required for an effective evaluation preflight performance and behaviors. Perhaps, the underlying reason why there are very minimal high fidelity studies that include the preflight process is due to the limited tools available to facilitate the production of needed materials (e.g. simulation of weather sources and flight planning devices). Currently, in order for researchers to develop preflight weather planning tools it requires a large team of diverse experiences, not many labs have the capability and funding to produce high fidelity environments and materials. In order to see an improvement in
the quality and generalizability of GA weather-related research, it is necessary to provide
scientists with easily accessible platforms and tools.

Although participants who used the performance support tool did have higher
information acquisition, preflight weather awareness, and inflight decision-making, currently in
this study, there is no way to determine which aspects of the intervention impacted these results.
Further investigation should be invested into separately assessing the effects of guidance on
weather information acquisition, weather interpretation, and risk guidance on preflight and
inflight performance.

**Conclusion**

For decades GA has accounted for the majority of weather-related accidents. Although we
have seen a slight decrease in the amount of GA weather-related accidents, the fatality rates
remains relatively unchanged. Low hour Inexperienced Private pilots have incurred the majority
of GA weather-related accidents, including VFR into IMC, which are the most lethal type of
weather-related incident. Previous research cites poor preflight planning practices and a lack of
aviation weather knowledge as key contributing factors to the high novice private pilot accident
and fatality rate. Although multiple advances have been made in the presentation of weather
products, few of these advanced have led to improved preflight and inflight performance. It may
be beneficial to consider new methods towards improving low experienced pilots’ aviation
weather practices. Perhaps by providing pilots with a performance support tool to aid them in the
preflight process, pilots’ understanding of weather, decisions, and inflight weather-related
behavior may improve. Thus, decision support tool technology could assist novice/intermediate
pilots through the aviation weather preflight process. The purpose of this study was to investigate
the effect of a performance support tool for weather preflight (PWDST) on pilots’ preflight performance and inflight performance.

Results from this study did provide more insight on preflight and inflight behaviors and performance. Study findings revealed the predictive relationship between risk perception during preflight planning and making go or no go decisions. Where, participants who displayed more accurate preflight risk perception, also were more likely to decide not to fly. As well as, the predictive relationship between Inflight Weather awareness and decision-making. Where, participants who were more aware of inflight weather developments, were also more likely to spend less time flying in degraded weather conditions. Study findings also revealed the affect a preflight weather support tool can have on preflight and inflight performance. Results revealed that PWDST assisted low hour inexperienced private pilots with weather information acquisition and weather awareness during the preflight stage. Additionally, PWDST also assisted low hour inexperienced private pilots with deciding how save a flight plan is and whether there are any weather-related risks associated with a flight plan. The PWDST also assisted Low Hour Inexperienced pilots with weather avoidance. Findings from this study suggest that preflight weather performance support tools may be able to assist low hour inexperienced with preflight planning practices and inflight and preflight decision-making. Furthermore, perhaps by creating weather and flight planning technology that also helps with weather accessibility, weather interpretation, and risk assessment we could improve preflight practices as well as preflight and inflight decision-making. As the scientific community continues to understand the various factor involved in novice pilot preflight and inflight performance, it is crucial to continue to consider operator knowledge, skills, and needs. As a community, we should strive to develop assistive
technology to help fit and fill user gaps in skills and knowledge and not attempt to try to redefine our users’ roles to fit our design limitations.
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https://doi.org/10.1016/j.ergon.2015.09.008


Default Question Block

Q35. What is your participant ID number?

Q1. With which gender do you most closely identify with?
   ○ Male
   ○ Female
   ○ Other
   ○ Prefer not to answer

Q2. What is your current age? (Please answer in numerical form. For example: 22)

Q3. Are you affiliated with Embry-Riddle Aeronautical University (ERAU)?
   ○ Current ERAU student
   ○ Current ERAU faculty or staff
   ○ ERAU Alumni
   ○ Not affiliated with ERAU

Q4. Are you currently receiving training towards a rating or a flight certificate?
   ○ Yes
   ○ No

Q5. What is the highest current pilot certification you hold?
   ○ Private
Q6.
Do you have an instrument rating? (If you are ATP, please answer yes)

☐ Yes
☐ No

Q7.
Do you hold a flight instructor certificate?

☐ Yes
☐ No

Q8.
Where did you complete the majority of your flight training?

☐ Part 61 (Local FBO)
☐ Part 141/142 Collegiate
☐ Part 141/142 Non-Collegiate
☐ Military
☐ International

Q9.
What is your main reason for flying?

☐ Training/School
☐ Self Transport
☐ Business
☐ Recreational
Q10. Have you flown a cross-country flight before (flights over 50 miles)?

○ Yes
○ No

Q11. Approximately how many **VFR cross-country** flights have you **planned**? (Please answer in numerical form. For example: 22)

   

Q12. Approximately how many **VFR cross-country** flights have you **flown**? (Please answer in numerical form. For example: 22)

   

Q13. Approximately how many **IFR cross-country** flights have you **planned**? (Please answer in numerical form. For example: 22)

   

Q14. Approximately how many **IFR cross-country** flights have you **flown**? (Please answer in numerical form. For example: 22)

   

Q15. What is your total flight hours? (Please answer in numerical form. For example: 101)

   

Q16. How many training hours do you have? (Please answer in numerical form. For example: 101)
Q17. Total number of hours under instrument flight rules (actual)? (Please answer in numerical form. For example: 101)

Q18. Total number of hours under instrument flight rules (simulated)? (Please answer in numerical form. For example: 101)

Q19. If applicable, how many hours have you flown as an instructor? (Please answer in numerical form. For example: 101)

Q20. Do you meet the currency requirements to act as the pilot-in-command (PIC) of an aircraft (have current flight review)?

   ○ Yes
   ○ No

Q21. If applicable, how many hours have you flown as pilot-in-command (PIC)? (Please answer in numerical form. For example: 101)

Q22. Within the past 90 days, approximately how many hours have you flown? (Please answer in numerical form. For example: 101)

Q23. Number of years you have been actively flying? (Please answer in numerical form. For example: 5)
Q24. In which region did you complete the majority of your total flight hours?

- Southwest – (Arizona, California, Colorado, Nevada, New Mexico, Utah)
- North Central – (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota)
- South Central – (Arkansas, Louisiana, Mississippi, Oklahoma, Texas)
- East Central – (Illinois, Indiana, Michigan, Ohio, Wisconsin)
- Northeast – (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia)
- Southeast – (Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee)
- Hawaii
- Alaska
- Other – International
- Other – Caribbean

Q25. In the last 12 months, how many cross-country flights have you flown? (Please answer in numerical form. For example: 10)

Q26. In the last 12 months, how many noncross-country flights have you flown? (Please answer in numerical form. For example: 10)

Q27. In the last 12 months, how many VFR hours have you logged? (Please answer in numerical form. For example: 10)

Q28. Have you ever encountered instrument meteorological conditions (IMC) while flying VFR?

- Yes
- No
Q29. If yes, what kinds of IMC?

Q30. In the last 12 months, how many IFR hours have you logged? (Please answer in numerical form. For example: 10)

Q31. In the last 12 months, how many IFR hours were in actual instrument meteorological conditions (IMC)?

Q32. Have you ever used a flight simulator software at home?
   ○ Yes
   ○ No

Q33. Have you ever used flight simulator software in training?
   ○ Yes
   ○ No

Q36. Have you ever used Prepar3D flight software before?
   ○ Yes
   ○ No

Q37. What type of aircraft do you actually fly? (Please provide the aircraft make model)
Q38. How many flight hours do you have in this aircraft? (Please answer in numerical form. For example: 10.)

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Last Click: 0 seconds
Page Submit: 0 seconds
Click Count: 0 clicks

Weather Training

Q42. What is your participant ID number?

Q43. Have you ever taken Class WX 301?
○ Yes
○ No

Q48. Have you ever taken Class WX 201
○ Click to write Choice 1
○ Click to write Choice 2
○ Click to write Choice 3

Q44. Have you ever received Weather Training?
○ Yes
○ No
Q45. If you have received Weather Training please explain where you received it and what topics the training covered:

Q43. For the following questions, please rate how much training you have had:
# Weather Training Questionnaire

## Default Question Block

What is your participant ID number?

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<th>A moderate amount</th>
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</tbody>
</table>

For the following questions, please rate how much training you have had:

1. How much training have you had in basic weather theory?
   - None at all [ ]
   - A little [ ]
   - A moderate amount [ ]
   - A lot [ ]
   - A great deal [ ]

2. How much training have you had in learning about cloud types (example: stratus clouds, cumulus clouds)?
   - None at all [ ]
   - A little [ ]
   - A moderate amount [ ]
   - A lot [ ]
   - A great deal [ ]

3. How much training have you had in learning about cloud formation (example: how clouds develop)?
   - None at all [ ]
   - A little [ ]
   - A moderate amount [ ]
   - A lot [ ]
   - A great deal [ ]

4. How much training have you had in identifying sky coverage (example: few, scattered, broken, overcast)?
   - None at all [ ]
   - A little [ ]
   - A moderate amount [ ]
   - A lot [ ]
   - A great deal [ ]

5. How much training have you had in identifying cloud height?
   - None at all [ ]
   - A little [ ]
   - A moderate amount [ ]
   - A lot [ ]
   - A great deal [ ]

6. How much training have you had in identifying visibility levels?
   - None at all [ ]
   - A little [ ]
   - A moderate amount [ ]
   - A lot [ ]
   - A great deal [ ]
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<th>A great deal</th>
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<td>8. How much training/experience do you have flying in IMC?</td>
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<td>9. How much training/experience do you have flying in simulated IFR?</td>
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<td>How many times have you encountered IMC weather conditions while inflight?</td>
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Appendix B
Product Usage Questionnaire

**Default Question Block**

**Q9. What is your participant ID number?**

**Q1.**
Please rate information value (how important the information is for preflight planning) for each of the following weather product sources.

<table>
<thead>
<tr>
<th>Source</th>
<th>Poor</th>
<th>Below Average</th>
<th>Average</th>
<th>Above Average</th>
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<td>Other</td>
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</table>
Q9. What is your participant ID number?

Q1.
Please rate information value (how important the information is for preflight planning) for each the following weather product sources.

<table>
<thead>
<tr>
<th>Product Source</th>
<th>Poor</th>
<th>Below Average</th>
<th>Average</th>
<th>Above Average</th>
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</table>

Q2. How frequently do you use the following weather sources for flight planning?
### Q3. Please rate information value (how valuable the information is) for each the following weather product sources.

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<thead>
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<th>Source</th>
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<th>Average</th>
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<th>Excellent</th>
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<tr>
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<td>METAR Graphical</td>
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<td>Pilot Reports (PIREP)</td>
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<tr>
<td>Terminal Aerodrome Forecast (TAF)</td>
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<td>Above Average</td>
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<tr>
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<td>☐</td>
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<tr>
<td>Convective SIGMET</td>
<td>☐</td>
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<td>☐</td>
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</tr>
<tr>
<td>SIGMET (Non-Convective)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Low-Level Significant Weather Chart (LL SigWX)</td>
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<tr>
<td>G-AIRMET Tango (Turbulence)</td>
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<td>☐</td>
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<td>☐</td>
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<tr>
<td>G-AIRMET Icing</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>G-AIRMET Sierra (Mtn/IFR)</td>
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<tr>
<td>G-AIRMET Freezing Level</td>
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<tr>
<td>Ceiling and Visibility Analysis (CVA)</td>
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<tr>
<td>Prognostic Charts</td>
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<tr>
<td>RADAR Coded Message (RCM)</td>
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<td>Surface Analysis</td>
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<tr>
<td>Center Weather Advisory (CWA)</td>
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<tr>
<td>Weather Depiction Chart</td>
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<tr>
<td>Infrared Satellite Images</td>
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<td>Above Average</td>
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<tr>
<td>Graphical Turbulence Guidance (GTG)</td>
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<td>Current Icing Product (CIP)/Forecast Icing Product (FIP)</td>
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<td>Other (please specify)</td>
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</tbody>
</table>

**Q4. How frequently do you use the following weather products for flight planning?**

<table>
<thead>
<tr>
<th>METAR Textual</th>
<th>Never</th>
<th>Sometimes</th>
<th>About half the time</th>
<th>Most of the time</th>
<th>Always</th>
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<tbody>
<tr>
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<td>Pilot Reports (PIREP)</td>
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<td>Terminal Aerodrome Forecast (TAF)</td>
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<td>Area Forecast (FA)</td>
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<td>SIGMET (Non-Convective)</td>
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<td>Low-Level Significant Weather Chart (LL SigWX)</td>
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<td>G-AIRMET Tango (Turbulence)</td>
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<td>About half the time</td>
<td>Most of the time</td>
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<tr>
<td>Single Site RADAR</td>
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<td>National Mosaic RADAR</td>
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<td>RADAR Coded Message (RCM)</td>
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<tr>
<td>Center Weather Advisory (CWA)</td>
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<tr>
<td>Weather Depiction Chart</td>
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<tr>
<td>Infrared Satellite Images</td>
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<tr>
<td>Graphical Turbulence Guidance (GTG)</td>
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<tr>
<td>Current Icing Product (CIP)/Forecast Icing Product (FIP)</td>
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<td>Other (please specify)</td>
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</tbody>
</table>

Q5. For each, please answer how frequently you use the following different forms of METARs and TAFs.

When using METARs, I use the **standard coded** version.

When using METARs, I use the standard **decoded** version.
<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Sometimes</th>
<th>About half the time</th>
<th>Most of the time</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>When using METARs, I use the <strong>graphical</strong> version.</td>
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</tr>
<tr>
<td>When using TAFs, I use the <strong>standard coded</strong> version.</td>
<td></td>
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</tr>
<tr>
<td>When using TAFs, I use the standard <strong>decoded</strong> version.</td>
<td></td>
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</tbody>
</table>

**Q6.**

Which weather products/sources do you rely on to receive up-to-date weather information during preflight and inflight? (example: METARS, TAFs, SIGMETs)

Check all that apply.

<table>
<thead>
<tr>
<th>Source</th>
<th>Preflight</th>
<th>Inflight</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATIS</td>
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<tr>
<td>AWOS/ASOS</td>
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<td>METAR/SPECI</td>
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</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Area Forecast (FA)</td>
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<tr>
<td>Winds and Temperature Aloft Forecast (FB Wind)</td>
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<td>Convective SIGMET</td>
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<tr>
<td>SIGMET (Non-Convective)</td>
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<tr>
<td>Low-Level Significant Weather Chart (LL SigWX)</td>
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<tr>
<td>G-AIRMET Sierra (Mtn/IFR)</td>
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<tr>
<td>G-AIRMET Icing</td>
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<tr>
<td>G-AIRMET Tango (Turbulence)</td>
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<tr>
<td>G-AIRMET Freezing Level</td>
<td></td>
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<tr>
<td>Service</td>
<td>Preflight</td>
<td>Inflight</td>
</tr>
<tr>
<td>------------------------------------------</td>
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</tr>
<tr>
<td>Ceiling and Visibility Analysis (CVA)</td>
<td>☐</td>
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<tr>
<td>Prognostic Charts</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Single Site RADAR</td>
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<td>☐</td>
</tr>
<tr>
<td>Ground-based RADAR</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>RADAR Coded Message</td>
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<td>☐</td>
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<tr>
<td>National Mosaic RADAR</td>
<td>☐</td>
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<tr>
<td>Surface Analysis</td>
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<tr>
<td>Center Weather Advisory (CWA)</td>
<td>☐</td>
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<tr>
<td>Weather Depiction Chart</td>
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<tr>
<td>Satellite Images</td>
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<tr>
<td>GTG</td>
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<tr>
<td>Current Icing Product (CIP)/Forecast Icing Product (FIP)</td>
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<tr>
<td>Telephone Information Briefing Service (TiBS)</td>
<td>☐</td>
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<td>HIWAS</td>
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<tr>
<td>Flight Watch</td>
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<tr>
<td>Other (please specify)</td>
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</tr>
</tbody>
</table>
Appendix C

Self-Efficacy

What is your participant ID number?

This questionnaire is designed to help us get a better understanding of how pilots view different aviation weather concepts/events/skills/knowledge. Please rate how confident you think you are at the following items.

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

<table>
<thead>
<tr>
<th>Cannot do at all</th>
<th>Moderately certain I can do</th>
<th>Highly certain I can do</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>20</td>
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<tr>
<td>30</td>
<td>40</td>
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<td>60</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>90</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

1. Overall flying ability
2. Overall meteorological knowledge
3. Knowledge of cloud formation
4. Knowledge of cloud types
5. Knowledge of temperature/dew point relationship

Knowledge of ceiling height and its effect on VFR conditions

Knowledge of fog type

Knowledge of fog formation

Knowledge of fog and its effect on VFR flight conditions

Knowledge of rain and its effect on VFR flight conditions

Knowledge of Instrument Meteorological Conditions (IMC) criteria

Knowledge of VFR weather conditions criteria

Knowledge of IMC effect on flight conditions

Knowledge of how VFR into IMC occurs

Knowledge of convective weather formation

Knowledge of convective weather phenomena

Knowledge of how convective weather effects flight conditions
Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

<table>
<thead>
<tr>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
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<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannot do at all</td>
<td>Moderately certain I can do</td>
<td>Highly certain I can do</td>
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</tbody>
</table>

6. Ability to problem solve during unexpected weather events while inflight (example, facing deteriorating conditions at destination).

7. Ability to detect different types of weather at night

8. Knowledge of turbulence

9. Knowledge of icing conditions

10. Knowledge of wind shear

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.
What is your participant ID number?

This questionnaire is designed to help us get a better understanding of how pilots view different aviation weather concepts/events/skills/knowledge during preflight planning. Please rate how confident you think you are at the following items.

*Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.*

<table>
<thead>
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<th>Cannot do at all</th>
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1. Overall weather flight planning ability

2. Knowledge of where to obtain appropriate weather briefings

3. Ability to correctly interpret weather information (current and forecast conditions)

4. Ability to access the weather information
11. Ability to navigate within clouds

12. Ability to navigate within fog

13. Ability to navigate within rain

14. Knowledge of density altitude

15. Ability to process/interpret weather conditions and how they may impact your flight
5. Knowledge of aviation weather product sources/providers (1-800-wx-brief, ADDS, DUAT/S)

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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6. Ability to use weather product sources/providers (ADDS, DUAT/S) for preflight planning

7. Knowledge of aviation weather products (e.g., METARS, TAFS, SIGMETS, AIRMETS, FIP, GTG)

8. Knowledge of aviation weather product limitations (e.g. product weather report updates)

9. Ability to read and interpret METARs Textual

Ability to read and interpret METARs Textual
10. Ability to read and interpret coded TAFs

Ability to read and interpret de-coded TAF

Ability to read and interpret METARs de-coded

Ability to read and interpret METARs coded

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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11. Ability to read and interpret PIREP

12. Ability to read and interpret SIGMET types (turbulence, icing, volcanic ash)

13. Ability to read and interpret Convective SIGMETs

14. Ability to read and interpret textual AIRMETs (TANGO, SIERRA, ZULU)
16. Ability to read and interpret CVA (Ceiling and Visibility Analysis)

17. Ability to read and interpret new Current Icing Product (CIP), and Forecast Icing Product (FIP),

Ability to read and interpret GTG

18. Ability to read and interpret satellite products

19. Ability to read and interpret winds aloft

20. Ability to read and interpret area forecasts
Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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21. Ability to read and interpret RADAR

22. Ability to plan a cross-country flight

23. Ability to create a flight plan for potential IMC encounters

24. Ability to use weather sources and products to create a flight plan at unfamiliar departure and destination airports

25. Ability to create a flight plan for a flight that involves VFR weather

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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26. Knowledge of
27. Ability to review and understand how weather data (current and forecast conditions) will affect visibility, turbulence, and aircraft performance for flight.

Ability to predict how future weather will develop based on weather information.

Ability to recognize trends in the weather information.

Ability to decide whether a flight is safe based on weather information.

Ability to decide a safe route out of a hazardous weather situation.

Ability to decide which weather products are necessary for proper preflight weather briefing.

Ability to decide how much weather information is adequate to make a go or no go decision.

Ability to decide whether to get more weather information while inflight.
Ability to decide when you need assistance with understanding weather information

Ability to pick a good diversion airport

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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Ability to use paper aeronautical chart (sectional and terminal) for preflight planning

Ability to use electronic aeronautical charts (sectional and terminal) for preflight planning

Ability to use plotter for preflight planning with paper aeronautical sectional chart

Ability to use E6B for preflight planning

Ability to plan a VFR
cross country flight

Ability to identify
deteriorating
weather inflight

Ability to estimate
cloud height while
inflight

Ability to estimate
visibility inflight

Ability to navigate
around deteriorating
weather safely

Ability to plan a
diversion in case of
deteriorating
weather

Ability to access
ASOS information
while inflight

Ability to access
AWOS while inflight

Ability to contact
HIWAS while inflight

Ability to get
weather information
from ATC while
inflight

Ability to decide
whether to divert
from a flight plan
while inflight
What is your participant ID number?

This questionnaire is designed to help us get a better understanding of how pilots view different aviation weather concepts/events/skills/knowledge during preflight planning. Please rate how confident you think you are at the following items.

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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2. Knowledge of where to obtain appropriate weather briefings

3. Ability to correctly interpret weather information (current and forecast conditions)

4. Ability to access the weather information

5. Knowledge of aviation weather product sources/providers
Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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9. Ability to access METARs on AWC

10. Ability to access TAFs on AWC

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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11. Ability to access PIREPs on AWC

12. Ability access SIGMET types (turbulence, icing, volcanic ash) on AWC

13. Ability to access Convective SIGMETs on AWC

14. Ability to access G-AIRMETs (TANGO, SIERRA, ZULU) on
15. Ability to access G-AIRMETs (Turb low, turb high, icing, freezing level, mountain obscuration, low-level wind shear, surface winds) on AWC

Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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16. Ability to access CVA (Ceiling and Visibility Analysis) on AWC

17. Ability to access GTG on AWC

18. Ability to access satellite products on AWC

19. Ability to access winds aloft on AWC

20. Ability to access area forecasts on AWC

Ability to access Current Icing Product (CIP) and Forecast Icing Products (FIP) on AWC
Rate your degree of confidence by recording a number from 0 through 100 using the scale given below that you are able to perform the following tasks.

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21. Ability to access interpret RADAR on AWC
Appendix D

Post Preflight Weather Situation Assessment

What is your Departure Airport?

Name 3 airports along your flight route:

What is your Destination Airport?

How much fuel will you burn on this flight?

Are there any aeronautical/navigational hazards associated with this flight?

Did you plan a diversion airport?

☐ Yes
☐ No

If yes, which airport did you pick for your diversion and why? (if you did not pick a diversion airport please respond "N/A")

Page 1 of 16
Please check all the weather products you checked while preflight planning for this flight plan:

- METAR
- TAF
- Area Forecast
- Winds Aloft
- Convective SIGMET
- SIGMET (non-convective)
- Low Level Significant Weather Chart (LLSW)
- G-Airmet Tango
- G-Airmet Icing
- G-Airmet Sierra
- G-Airmet Freezing Level
- Ceiling and Visibility (CVA)
- Prognostic Chart
- Single Site RADAR
- National Mosaic RADAR
- RADAR Coded Message
- Surface Analysis
- Center Weather Advisory
- Weather Depiction
- Satellite Images
- Graphical Turbulence Guidance
- Current Icing Product
- Other

**Departure**

Please describe the weather along your route:


Please describe the weather in the Departure airport area:


What was the visibility in the departure area? (in numerical form; eg. XXSM)


What was the cloud height in the departure area? (in numerical form; eg. XXSM)
What weather phenomena was present in the departure area?

What flight category weather is present at the departure airport?
- IFR
- VFR
- MVFR

Does this weather meet your personal minimums?
- Yes
- Maybe
- No

If yes please explain how it violates your personal minimums:

Which weather products assisted in providing you with information on weather at the departure airport and area.

- METAR
- TAF
- Area Forecast
- Winds Aloft
- Convective SIGMET
- SIGMET (non-convective)
- Low Level Significant Weather Chart (LLSWC)
- G-Airmet Tango
- G-Airmet Icing
- Prognostic Chart
- Single Site RADAR
- National Mosaic RADAR
- RADAR Coded Message
- Surface Analysis
- Center Weather Advisory
- Weather Depiction
- Weather Satellite Images
- Graphical Turbulence Guidance
Enroute

Please describe the weather enroute along your flight route:


Please provide a summary of the visibility enroute? (in numerical form; eg. XXSM)


Please provide a summary of the cloud heights and types enroute? (in numerical form; eg. XXSM)


What weather phenomena was present enroute along your flight route?


What flight category weather is present enroute along the flight route?

- IFR
- VFR
- MVFR

Does this weather meet your personal minimums?

- yes
If no please explain how it violates your personal minimums:

Which weather products assisted in providing you with information on weather conditions enroute along the flight route.

- METAR
- TAF
- Area Forecast
- Winds Aloft
- Convective SIGMET
- SIGMET (non-convective)
- Low Level Significant Weather Chart (LLSW)
- G-Airmet Tango
- G-Airmet Icing
- G-Airmet Sierra
- G-Airmet Freezing Level
- Ceiling and Visibility (CVA)
- Prognostic Chart
- Single Site RADAR
- National Mosaic RADAR
- RADAR Coded Message
- Surface Analysis
- Center Weather Advisory
- Weather Depiction
- Satellite Images
- Graphical Turbulence Guidance
- Current Icing Product
- Other

How does the weather seem to be developing?

- Better weather conditions
- Worse weather conditions
- Relatively the same

Please explain how the weather conditions seem to be developing:
Destination

Please describe the weather in the Destination airport area:

What was the visibility in the destination area? (in numerical form; eg. XXSM)

What was the cloud height in the destination area? (in numerical form; eg. XXSM)

What weather phenomena was present in the destination area?

What flight category weather is present at the destination airport?

- IFR
- VFR
- MVFR

Does the weather at your destination airport meet your personal minimums?

- yes
- Maybe
- No

If yes please explain how it violates your personal minimums:
Which weather products assisted in providing you with information on weather conditions at the destination airport and area.

- METAR
- TAF
- Area Forecast
- Winds Aloft
- Convective SIGMET
- SIGMET (non-convective)
- Low Level Significant Weather Chart (LLSW)
- G-Airmet Tango
- G-Airmet Icing
- G-Airmet Sierra
- G-Airmet Freezing Level
- Ceiling and Visibility (CVA)
- Prognostic Chart
- Single Site RADAR
- National Mosaic RADAR
- RADAR Coded Message
- Surface Analysis
- Center Weather Advisory
- Weather Depiction
- Satellite Images
- Graphical Turbulence Guidance
- Current Icing Product
- Other

How does the weather seem to be developing?

- Better weather conditions
- Worse weather conditions
- Relatively the same

Please explain how the weather conditions seems to be developing:

Risk and Decisions

This flight could be risky due to weather conditions

Strongly  Disagree  Somewhat  Neither agree  Somewhat  Agree  Strongly
There is no risk associated with the weather conditions at the Departure Airport.

Based on the provided information this flight should be safe to fly VFR and land at the proposed destination airport

Would you decide to fly this vfr flight plan?

- yes
- No

Page 8 of 16
Why?

Is there anything concerning about this vfr flight plan?

Block 5

Please provide the most detailed summary of what weather information each product reported for your departure, enroute, and destination areas along your flight route:

METAR summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

TAF summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

Area Forecast summary for weather conditions along the flight route:
"If there is not weather present, please respond with "no weather report". If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

Winds Aloft summary for weather conditions along the flight route:

"If there is not weather present, please respond with "no weather report". If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

Convective SIGMET summary for weather conditions along the flight route:

"If there is not weather present, please respond with "no weather report". If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

SIGMET non-convective summary for weather conditions along the flight route:

"If there is not weather present, please respond with "no weather report". If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination
G-Airmet Tango summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

G-Airmet Sierra summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

G-Airmet Icing summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

G-Airmet Freezing Level summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination
Ceiling and Visibility Analysis (CVA) summary for weather conditions along the flight route:

"If there is not weather present, please respond with " no weather report". If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

Prognostic Charts summary for weather conditions along the flight route:

"If there is not weather present, please respond with " no weather report". If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

Single Site RADAR summary for weather conditions along the flight route:

"If there is not weather present, please respond with " no weather report". If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

National Mosaic RADAR summary for weather conditions along the flight route:

"If there is not weather present, please respond with " no weather report". If you do not know, or if you do not remember, please respond "N/A".*
RADAR Coded Message summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Surface Analysis summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Center Weather Advisory (CWA) summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".
If you do not know, or if you do not remember, please respond "N/A".*

Weather Depiction Chart summary...
*If there is not weather present, please respond with "no weather report".*
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

Satellite Image summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".*
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

Graphical Turbulence Guidance (GTG) summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".*
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination

Current Icing Product and Forecast icing Product (CIP/FIP) summary for weather conditions along the flight route:

*If there is not weather present, please respond with "no weather report".*
If you do not know, or if you do not remember, please respond "N/A".*

Departure
Enroute
Destination
Appendix E

Inflight Weather Situation Assessment

Did you land at the destination airport

- Yes
- No

Did you plan a diversion airport?

- Yes
- No

If yes, which airport did you pick for your diversion and why? (If you did not pick a diversion airport please respond "N/A")

If yes, which airport did you pick for your diversion and why? (If you did not pick a diversion airport please respond "N/A")

Did you access any inflight weather information

- Yes
- No

Please specify what weather information you collected while inflight.

Please specify what weather information you collected while inflight.

Departure

Please describe the weather along your route:

Please describe the weather along your route:
Please describe the weather in the Departure airport area:

What was the visibility in the departure area while inflight? (in numerical form; eg. XXSM)

What was the cloud height in the departure area while inflight? (in numerical form; eg. XXSM)

What weather phenomena was present in the departure area while inflight?

What flight category weather was present at the departure airport?

- IFR
- VFR
- MVFR

Did the weather meet your personal minimums?

- yes
- Maybe
- No

If no please explain how it violates your personal minimums:
Which weather products provided the most accurate representation of actual weather conditions in the departure airport and area.

- [ ] METAR
- [ ] TAF
- [ ] Area Forecast
- [ ] Winds Aloft
- [ ] Convective SIGMET
- [ ] SIGMET (non-convective)
- [ ] Low Level Significant Weather Chart (LLSW)
- [ ] G-Airmet Tango
- [ ] G-Airmet Icing
- [ ] G-Airmet Sierra
- [ ] G-Airmet Freezing Level
- [ ] Ceiling and Visibility (CVA)
- [ ] Prognostic Chart
- [ ] Single Site RADAR
- [ ] National Mosaic RADAR
- [ ] RADAR Coded Message
- [ ] Surface Analysis
- [ ] Center Weather Advisory
- [ ] Weather Depiction
- [ ] Satellite Images
- [ ] Graphical Turbulence Guidance
- [ ] Current Icing Product
- [ ] Other

**Enroute**

Please describe the weather you experienced enroute while inflight:


Please provide a summary of the visibility enroute? (in numerical form; eg. XXSM)


Please provide a summary of the cloud heights and types enroute? (in numerical form; eg. XXSM)


What weather phenomena was present enroute along your flight route?
What flight category weather is present enroute along the flight route?

- IFR
- VFR
- MVFR

Does this weather meet your personal minimums?

- Yes
- Maybe
- No

If no please explain how it violates your personal minimums:

Which weather products provided you the most accurate representation of actual weather conditions in enroute while inflight.

- METAR
- TAF
- Area Forecast
- Winds Aloft
- Convective SIGMET
- SIGMET (non-convective)
- Low Level Significant Weather Chart (LLSW)
- G-Airmet Tango
- G-Airmet Icing
- G-Airmet Sierra
- G-Airmet Freezing Level
- Ceiling and Visibility (CVA)
- Prognostic Chart
- Single Site RADAR
- National Mosaic RADAR
- RADAR Coded Message
- Surface Analysis
- Center Weather Advisory
- Weather Depiction
- Satellite Images
- Graphical Turbulence Guidance
- Current Icing Product
- Other
How did the weather seem to develop during the enroute part of the flight?

- better weather conditions
- worse weather conditions
- relatively the same

Please explain in detail how the weather conditions seemed to be developing during your flight enroute:

Destination

Please describe you the weather encountered inflight in the Destination airport area:

What was the visibility at the destination area? (in numerical form; eg. XXSM)

What was the cloud height in the destination area? (in numerical form; eg. XXSM)

What weather phenomena was present in the destination area?

What flight category weather was present at the destination airport?
Did the weather at your destination airport meet your personal minimums?

- Yes
- Maybe
- No

If yes please explain how it violates your personal minimums:

Which weather products provided the most accurate representation of the actual weather conditions in destination airport and area.

- METAR
- TAF
- Area Forecast
- Winds Aloft
- Convective SIGMET
- SIGMET (non-convective)
- Low Level Significant Weather Chart (LLSW)
- G-Airmet Tango
- G-Airmet Icing
- G-Airmet Sierra
- G-Airmet Freezing Level
- Ceiling and Visibility (CVA)
- Prognostic Chart
- Single Site RADAR
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- RADAR Coded Message
- Surface Analysis
- Center Weather Advisory
- Weather Depiction
- Satellite Images
- Graphical Turbulence Guidance
- Current Icing Product
- Other

How did the weather seem to be developing?
better weather conditions
worse weather conditions
relatively the same

Please explain how the weather conditions seemed to be developing:

Risk and Decisions

The flight was an unsafe flight due to hazardous weather conditions.

Strongly Disagree Disagree Somewhat disagree Neither agree nor disagree Somewhat agree Agree Strongly agree

There were no risks associated with the weather conditions at the Departure Airport.

Strongly Disagree Disagree Somewhat disagree Neither agree nor disagree Somewhat agree Agree Strongly agree

There were no risks associated with the weather conditions en-route along the flight route.

Strongly Disagree Disagree Somewhat disagree Neither agree nor disagree Somewhat agree Agree Strongly agree

There were no risks associated with conditions at the Destination Airport.
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All my decisions made while inflight were safe.

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All my decisions made while inflight complied with VFR flight rules.

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The weather I encountered inflight was similar to the forecasted weather reported during preflight planning.

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I was surprised by the weather I encountered inflight.

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I wish I gathered more weather information while inflight.

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<th>Neither agree nor disagree</th>
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My preflight planning prepared me for the flight route and the weather encountered inflight.

- Strongly Disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Weather deteriorated along my flight route from VFR into IFR.

- Strongly Disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Would you decide to fly this VFR flight plan?

- Yes
- No

Why?

Is there anything concerning about this VFR flight plan?
Preflight Weather Decision Support Tool (PWDST): User-Centered Design Process and Usability Validation

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Embry-Riddle Aeronautical University, Daytona Beach, FL

General Aviation flight operations have been negatively affected by the slow decreasing weather related accident rate for the last 20 years. Upon further investigation, research suggests, that poor preflight planning and a lack of aviation weather experience and knowledge may be contributing factors to the stagnant weather related accident rate. Our team developed a Preflight Weather Decision Support Tool (PWDST) to help novice pilots access, interpret, and apply weather information. We used a user-centered design process which involved an initial task analysis, low-fidelity prototyping, low-fidelity usability testing, user interviews and expert review. This study assessed and compared the perceived usability, difficulty, and the system assistance satisfaction of the PWDST. Participants (n=9) completed a usability study and a series of surveys during, as well as, after the completion of the preflight planning scenario. A series of Mann-Whitney U Tests were conducted to compare the difference between Private Pilot and Certified Flight Instructors (CFI) perceived usability, difficulty, and system assistance satisfaction ratings. Results indicated, there were no significant differences between group ratings. Overall, both groups reported above average usability, system assistance and low difficulty rating for the PWDST. Future research and possible implications are discussed.

INTRODUCTION

The General Aviation (GA) weather related accident rate has remained the slowest decreasing accident rate within GA flight operations (FAA, 2010; Fultz & Ashley, 2016; AOPA, 2008). Previous research indicates the majority of these accidents result in fatalities, with Visual Flight Rule flight operations into Instrument Meteorological Conditions (VFR into IMC) being the most hazardous type of weather related accident (FAA, 2010; Fultz & Ashley, 2016; Goh & Wiegmann, 2001; AOPA, 2008). Primarily, low hour inexperienced private pilots incur the majority of weather related accidents (Capobianco & Lee, 2001; Fultz & Ashley, 2016). Multiple sources have identified poor preflight planning and a lack of aviation weather knowledge and skills as a possible contributing factors for inadequate inflight weather avoidance and VFR into IMC incidents (Blickensderfer et al.). To address this need, our team developed an aviation weather decision support tool. The tool is designed to assist low hour inexperienced private pilots with the aviation weather preflight planning process. The purpose of this study is to assess the usability of the Preflight Weather Decision Support Tool (PWDST).

Background

Preflight Planning. Weather planning is a crucial component of the preflight planning process. During weather preflight planning pilots access multiple weather sources, interpret weather products, and develop a flight plan. This process is intended to better equip pilots with a mental model of current and developing weather conditions along their flight route. The FAA divides the preflight process into three major components, perceive, process, and perform (Parson et al., 2005).

The weather preflight planning process begins with the “perceiving” phase, where pilots collect an array of weather
products. During weather information acquisition pilots are able to search and navigate various weather sources of differing modalities to form a holistic mental model of prevailing and forecasted weather conditions, including: potable weather applications, websites, and call in services (e.g. Aviation Weather Center (AWC), 1-800 Weather Brief Call-in, and Foreflight). However, a pilot’s ability to navigate these weather sources depends on the pilots’ familiarity with the source, the usability of the source interface, and the quality of the provided weather information. Therefore, limitations within the information acquisition stage may hinder the quantity and quality of information pilots receive, which may in turn result in an inadequate and inaccurate pool of weather information (Parson et al., 2005).

After gathering all the weather information, pilots progress to the “processing” phase of the task (Parson et al., 2005). Weather product interpretation can be quite challenging, especially for inexperienced pilots who lack foundational understanding of basic weather principles (Blickensderfer et al., 2018). The majority of weather information is encoded and may require the user to access legends and/or have previous experience with the product to facilitate product interpretation (e.g. METARS, TAFs, Wind Aloft, Station Plots). Failure to accurately interpret weather information could lead to a dismal distortion of the received weather information. Furthermore, defective reception of weather information can influence the pilot’s mental model of prevalent weather conditions and may result in hazardous weather behavior (Blickensderfer et al., 2018).

“Perform” is the final stage of the weather preflight planning process (Parson et al., 2005). Subsequent to the interpretation of the received weather information, pilots must apply the extrapolated weather information to their current aeronautical flight plan. Considering this phase requires pilots to have correct completion of both the Perceiving, and processing phase, the perform stage may be the most challenging component of the entire task. Pilots need to understand the prevailing weather conditions, as well as, the flight safety risks each weather phenomena may pose for their specific flight plan. Therefore, this task will demand the user to function at a higher level of cognitive processing and may require previous experience.

Since the weather preflight planning phase is a layered task, deficient performance on any weather planning phase could invalidate all the previous and future task phases. This may result in uninformed preflight and inflight decision making. Previous research highlighted poor product usability, inadequate weather knowledge and skills, risk assessment, and decision making as contributing factors for VFR into IMC incidents (NTSB, 2005; Capobianco & Lee, 2001). The effects of these contributing factors may begin in the preflight process and continue to develop throughout the inflight process, resulting in poor weather avoidance and hazardous inflight decision making.

**Decision Support Tools.** A solution to the GA weather problem has been attempted from various perspectives and fields. This includes the development of increasingly adaptive and dynamic weather displays. Although the development of new weather technology for preflight and in the cockpit interfaces may improve certain aspects of situational awareness, the majority of these technological advances have failed to prevent hazardous weather encounters inflight (Latorella & Chamberlain, 2002; Yuchnovicz et al., 2001; Beringer and Ball,
It may be that aviation weather and flight planning tasks are too complicated and cognitively taxing to simply be addressed by the introduction of new technologies. Instead, new approaches that compensate for the users’ lack of meteorological knowledge and skills is necessary to fill the gap between the user and the weather planning task. King, Ortiz, Blickensderfer, and Christy (2018) explored the possibility of applying Decision support tool technology to the aviation weather preflight planning task. Additionally, Ortiz, Blickensderfer, and Christy (2018) suggest decision support tool technology could address the disparity of skill and knowledge between the user and task, as well as, improve overall preflight and inflight performance. Furthermore, with certain precautions, a preflight decision support tool may offer just enough assistance to help novice private pilots operate at a higher level of performance and safety. In order to promote improved performance, King, Ortiz, Blickensderfer, and Christy (2018) suggest the preflight decision support tool should apply specific levels of automation to specific tasks, consider and avoid the negative impacts of automation, provide training for the preflight weather decision support tool, include a multidisciplinary team for product development, consider usability, and integrate system adaptability.

Preflight Weather Decision Support Tool Description & Development. In this study, our team developed a prototype preflight weather decision support tool (PWDST). The tool was developed by a multidisciplinary team including, two human factors specialists, a meteorologist, a private pilot, and a gold standard flight instructor. The purpose of the tool is to assist novice low hour private pilots with the weather portion of the preflight planning process. The PWDST assists pilots with accessing, interpreting, and applying weather information in context of their current flight plan. The PWDST uses a mixture of usability, low level information/analysis automation, and expertise knowledge to guide pilots through establishing their personal minimums, determining weather checking airports, accessing, interpreting, and applying weather information, and assessing weather risks. Each team member was included in the application development and beta testing.

Figure 1. PWDST: Low Level Significant Weather Chart Section Flow
questions to encourage the application of the interpreted weather information to their flight.

PWDST Development

The PWDST underwent four major phases of review and modifications. The first step in the PWDST development process included a thorough Preflight Planning Task analysis. This task analysis identified the major and minor possible limitations associated with completing weather preflight planning using AWC and traditional preflight planning tools. Next, we interviewed a series of private pilots and instructors to gain a better understanding of common hindrances to novice pilots while preflight weather planning. Through the use of target market feedback and Subject Matter expert guidance, we developed the first PWDT prototype. Next, the PWDST underwent an iterative process including a series of expert reviews and modifications. Data and feedback from expert reviewers and subject matter experts were incorporated into the future designs in order to improve the usability, as well as, content and face validity of the tool. Now, that we have completed the development process of our final prototype, it is imperative to observe and assess the usability of the interface and gauge users’ impressions of the system.

METHOD

Experimental Design

The study was a mixed group design. The purpose of the study was to assess the usability of the PWDST tool, with consideration for experience. There were two levels of experience, the novice level included Private Pilots, while the expert level included Certified Flight Instructors (CFI). Both groups completed the same preflight scenarios using the PWDST tool.

Participants

Nine pilots ($M_{age} = 24.11$ (SD= 5.11)) from a Southeastern United States university were recruited to participate in this study. Four participants held a private pilot license ($Mdn_{flight hours} = 102.10$ (SD= 55.00)) and five pilots were CFI rated ($Mdn_{flight hours} = 710.00$ (SD= 575.20). The majority of the participants completed their flight training at a Part 141 facility. The study was reviewed and approved in advance by the Embry-Riddle Aeronautical University Institutional Review Board for the protection of our participants. For incentive, each participant received $25 dollars for the completion of this study.

Materials

The following materials were used in this study: PWDST, PWDST Training Video, and the Simulated Preflight Task: Preflight Weather Decision Support Tool. The Preflight Decision Support Tool was wire-framed using Google Drive App Draw.io and the high fidelity mockup was created with AXURE software student license. The purpose of this tool is to guide users through the preflight process and improve preflight and inflight performance. The Preflight Weather Decision Support Tool (PWDST) is comprised of three main components, the preflight guide, the personal minimums sections, and the risk assessment and checklist output.

PWDST Training Video. This six-minute video was developed using Microsoft Video Maker. The purpose of the training video is to guide users through the main components of the PWDST. The video illustrates how to navigate the tool’ preflight guide, the personal minimums sections, and the risk assessment and checklist output.

Experimental Task: The task for this study required participants to perform a
preflight an aviation weather scenario. The flight scenario is a VFR Into IMC scenario. In the scenario, the scheduled flight route starts at the departure airport, KAEL, and ends at the destination airport, KDTL. During the preflight scenario, participants were asked to use the PWDST to access and interpret weather for their flight route. The following weather products were used in this scenario:

- Big Picture Products: Low Level Significant Weather Chart, Surface Analysis, Satellite, Radar
- Hazard Products: Convective SIGMETs and G- AIRMETs
- Visibility Products: METARs

Surveys Measures. All surveys were developed online using Qualtrics survey software. The participants completed all the surveys at the data collection site at their own pace. This study included the following surveys: 1) Demographic questionnaire, 2) After Scenario Questionnaire, 3) Subjective Mental Effort Questionnaire, 4) System Usability Scale, 5) and a Participant Rater Form.

1) Demographic Questionnaire: The demographic survey is composed of 84 items. The demographic survey items cover topics such as participant age, flight training, flight experience, weather training, and weather experience.

2) After Scenario Questionnaire: The After Scenario Questionnaire is a user satisfaction survey (Lewis, 1991). This scale has three items that prompt participants to rate on a scale from 1-7 their overall satisfaction with the system. In this study, this scale was used to assess participants’ satisfaction with systems support and design for various assigned tasks and activities.

3) Subjective Mental Effort Questionnaire: This scale is a one item scale that measures participants’ perceived difficulty of tasks (Sauro & Dumas, 2009). The Scale ranges from (0) Not at all hard to do, (10) Tremendously hard to do, and (150). In this study, this questionnaire was used to assess participants perceived mental effort while completing various assigned tasks.

4) System Usability Scale: This survey questions users on their perceived usability for a particular system (Brooke, 1996). The survey has 10 items; users are prompted to rate how much they agree with each item on a scale from one (Strongly Disagree) to five (Strongly Agree). This scale was used to survey participants’ overall impressions about the system.

5) Participant Rater Form: These questions prompt the participant about their system assistance satisfaction and difficulty for completing each task. For the difficulty rating for completing each task using the PWDST, the options range from 1 (Very Difficult) to 7 (Very Easy). While for the system assistance satisfaction scale, participants are asked to rate their satisfaction with the support information provided by the PWDST for each task, with options ranging from 1 (strongly disagree) to 7 (strongly agree).

Procedure
After an initial briefing, participants were asked to sign a consent form. Then participants used a computer to complete the online demographic questionnaire. Next, participants were briefed and trained on the Preflight Weather Decision Support Tool and completed the post-training quiz. Participants then completed a series of activities using the Preflight Weather Decision Support Tool system on an iPad. For the activity, participants were asked to complete weather preflight planning using the app and access, interpret, and apply weather products from the Aviation Weather Center Website (AWC.org). After each
activity participants answered questions from Participant Rater Form. After all activities were completed, participants completed the System Usability Scale, Subjective Mental Effort Questionnaire and the After-scenario questionnaire for their overall experience with the PWDT. Lastly, participants were debriefed and compensated.

RESULTS

A series of Mann-Whitney U-Tests were conducted in order to examine the differences in between Private Pilot and Certified Flight Instructors impressions, satisfaction, and rated usability of the PWDST application. Results indicated, there were no significant differences between Private Pilot and Certified Flight Instructor impressions, satisfaction, and rated usability of the app.

System Usability Scale (SUS)
For the overall system usability on a scale from 0-100, both groups rated the usability above 68, which is considered above average. Although, Private pilots reported a slightly higher system usability score, there were no significant differences between groups (U = 9.00, z = -2.47, p = .81, r = -.08).

After Scenario Questionnaire
Overall system satisfaction was reported on a scale from 1 (strongly disagree) to 7 (strongly agree), both groups average rated the overall system satisfaction above 5. Results indicated, there were no significant difference between groups for overall system satisfaction (U = 7.00, z = -7.47, p = .46, r = -.25). However, Private pilots’ reported system satisfaction was slightly higher than CFI reported system satisfaction.

Subjective Mental Effort Questionnaire
Overall perceived difficulty completing tasks using the PWDST system was reported on a scale from (0) Not at all hard to do, (110) Tremendously hard to do, and (150). In this study both groups average rating was lower than 25, A bit hard to do. Results indicated, there were no significant difference between groups for overall system satisfaction (U = 9.00, z = -2.56, p = .80, r = -.09). However, Private pilots’ reported system satisfaction was slightly higher than CFI reported system satisfaction.

Participant Rater form
For each product within the Big Picture, Hazards, And Visibility product sections, participants completed a difficulty scale with options ranging from 1 (Very Difficult) to 7 (Very Easy). Additionally, participants also completed a satisfaction scale for each product with options ranging from 1 (strongly disagree) to 7 (strongly agree). Six Mann Whitney U Tests were ran to compare means between Private Pilots and CFI, results indicated, there were no significant difference between groups for participant rated difficulty and satisfaction with system assistance for: Big Picture (rated difficulty: U = 3.5, z = -1.63, p = .10, r = -.05) (rated system assistance satisfaction: U = 4.00, z = -1.50, p = .14, r = -.05), Hazards (rated difficulty: U = 9.50, z = -.13, p = .90, r = -.04) (rated system assistance satisfaction: U = 7.00, z = -.81, p = .42, r = -.03), and Visibility products (rated difficulty: U = 2.00, z = -.216, p = .03, r = -.72) (rated system assistance satisfaction: U = 5.50,z=1.15,p=.25,r=-.38).

Table 1: Survey Measure Mean Scores for Private Pilots and Certified Instructors.
Results indicated there were no significant differences between Private pilots and CFI impressions, system assistance satisfaction, and perceived usability of the PWDST application. Furthermore, Private pilots reported higher ratings for usability, system satisfaction, and lower ratings for subjective mental effort. Although, the PWDST was initially designed to assist low hour private pilots through the weather preflight planning process. Results suggest that despite the difference in flight experience and training both groups had positive feedback about the application’s support information and the overall usability for weather preflight planning tasks.

Further research should be invested into a more detailed analysis of each application interface and the various possible errors and limitations the application may introduce during each phase and task of the preflight planning process. Additionally, future research should be invested into investigating the effects the PWDST may have on preflight and inflight performance for novice and experienced pilots.

**DISCLAIMER**

The views expressed in this paper are those of the authors and do not necessarily represent the organization with which they are affiliated.

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