DEVCOM DAC-TR-2022-096
September 2022

User-Centered Design of a Weather Dynamic Infographic for U.S. Army Aviation

by Derek Millard, Bradley Davis, D'Asia Betts, Gabriel Guy, Jazlyn Meeks, and Corinne Ridgell

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DOD Historically Black College/University and Minority Institution Summer Research Program

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED (From - To)
September 2022	Technical Report	06/01/22 – 08/09/22

4. TITLE AND SUBTITLE
User-Centered Design of a Weather Dynamic Infographic for U.S. Army Aviation

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Derek Millard, Bradley Davis, D’Asia Betts, Gabriel Guy, Jazlyn Meeks, and Corinne Ridgell

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Director
DEVCOM Analysis Center
6896 Mauchly Street
Aberdeen Proving Ground, MD 21005

8. PERFORMING ORGANIZATION REPORT NUMBER
DEVCOM DAC-TR-2022-096

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Access to relevant weather information is essential for pilots to make informed decisions while enroute. Currently, pilots are informed aurally via reporting stations, which may make information retention more difficult. A weather dynamic infographic was designed to increase Army pilots' situational awareness and decision quality, providing Army pilots with a convenient and concise method of viewing relevant weather information. This study utilized a user-centered design approach, with initial design concepts created from various influences including commercial and aviation weather applications, which were then demonstrated to Army pilots and subject matter experts for input. Participant ratings of usability, situation awareness, and information importance were collected along with comments for improvement. Overall, the usability and information importance ratings were relatively high. The information in the advisory/alerts component was rated higher than that of the current conditions and forecast components. These results suggest that the advisory/alerts component aided the most in a pilot’s decision-making process.

15. SUBJECT TERMS
Dynamic Infographic (DIG), User-Centered Design, Army Aviation, Weather, Heads-Up Display, Future Vertical Lift, Holistic Situational Awareness—Decision Making

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Derek Millard
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UU	29	19b. TELEPHONE NUMBER (include area code) 256-313-2535

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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Acknowledgements

The U.S. Army Combat Capabilities Development Command (DEVCOM) Analysis Center, known as DAC, recognizes the following individuals for their contributions to this report:

Dr. Thomas W. Davis
Anna Mares
Gina Hartnett
Jamison Hicks
Dave Durbin

1. INTRODUCTION

Access to relevant weather information is essential for pilots to make informed decisions while enroute. Currently, pilots are informed aurally via reporting stations. Aural weather information may be more difficult for pilots to retain relevant information for reference. A weather dynamic infographic (DIG) was designed to increase Army pilots' situational awareness and decision quality, providing Army pilots with a convenient and concise method of viewing relevant weather information. The weather DIG potentially increases pilots' ability to integrate weather and spatial flight information more effectively. This study utilized a user-centered design approach with initial design concepts created from various influences including commercial and aviation weather applications that were then demonstrated to Army pilots and subject matter experts for input.

The focus of the study was to evaluate the designed weather DIG to determine the relevant information and how it is best displayed. Future aviation technology will allow the designed weather DIG to be displayed and integrated with an aircraft interface and/or heads-up display to align with future Army technology requirements.

This effort was the product of four students in the Department of Defense Historically Black Colleges and Universities/Minority Institutions Summer Research Program and their mentors at the U.S. Army Combat Capabilities Command (DEVCOM) Analysis Center, known as DAC. Together, the team conceived, prototyped, and programmed the weather DIG. Additionally, they conducted a user jury at DAC's Immersive Systems Integration Center located at the University of Alabama in Huntsville during Summer 2022. Since the design concepts were all novel, there were no a priori expectations about the pilot's preferences.

This project supports the Army's Holistic Situational Awareness and Decision Making Program and Future Vertical Lift by evaluating concepts and capabilities for the Army's next-generation aviator.

2. METHODOLOGY

2.1. Participants

Researchers leveraged existing contacts in the Army aviation community to recruit a total of five participants, including one active-duty Army pilot, one retired Army pilot, and three subject matter experts.

Demographic data were collected with a short questionnaire (Figure A-1). Four of the five participants were male (ages 38–62, M = 50.8). Pilots were all experienced (M = 2700 flight hours) with an average of 31 years of military service.

2.2. Weather DIG Design

To design the weather DIG in Figure 1, researchers pulled from various sources of weather information and symbology like the Federal Aviation Administration (FAA, 1958), electronic flight bags such as ForeFlight (2007), GPS devices (1996), and weather applications on smartphones. The various weather categories found were established and icons were developed to represent each one. Icons were created by editing free images gathered from the internet (The Noun Project, 2010) on the free and open-source image-editing software GIMP (1996). The icons were initially matched with their relevant alphanumeric data to create prototype symbology in a slideshow.

The weather symbology was then categorized under three components to create the baseline infographic design: current conditions, advisory/alerts, and forecasts. At this stage, functionality was specified, such as allowing the visibility of each component and/or the symbology within each component to be manually or automatically toggled (or “decluttered”) depending on what is currently relevant to the pilot. It was also determined that a minimap would be necessary to show weather information plotted over the local map. Relevant symbology in the DIG was specified to function as buttons that toggle the visibility of their associated components and minimap modes; these buttons are indicated by a faint gray highlight on the DIG (Figure 1).

The weather DIG was then implemented in the game engine software Unreal Engine 5 (2004). This allowed researchers to create a simulated flight environment, shown in Figure 2, that included a UH-60A helicopter model and weather effects such as clouds, rain, fog, lightning, and thunder. A heads-up display that included the weather DIG, a minimap, and flight symbology was then simulated as an overlay on the environment.

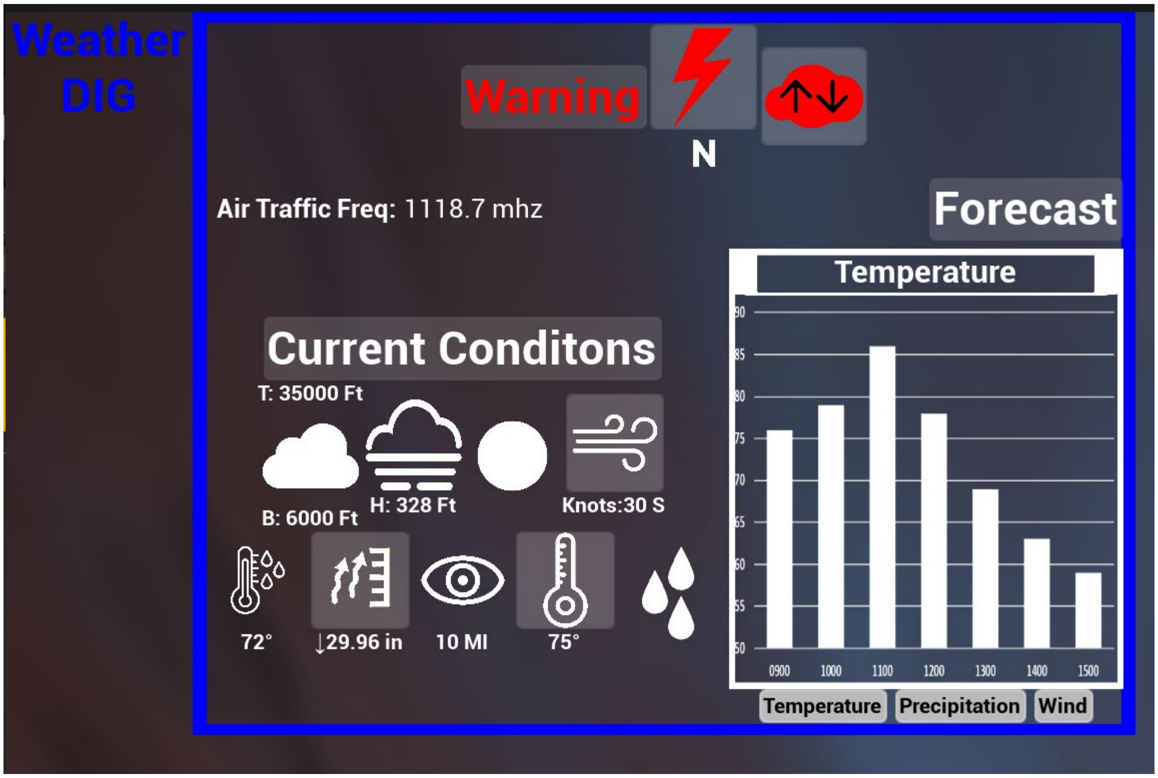

Figure 1. Weather DIG

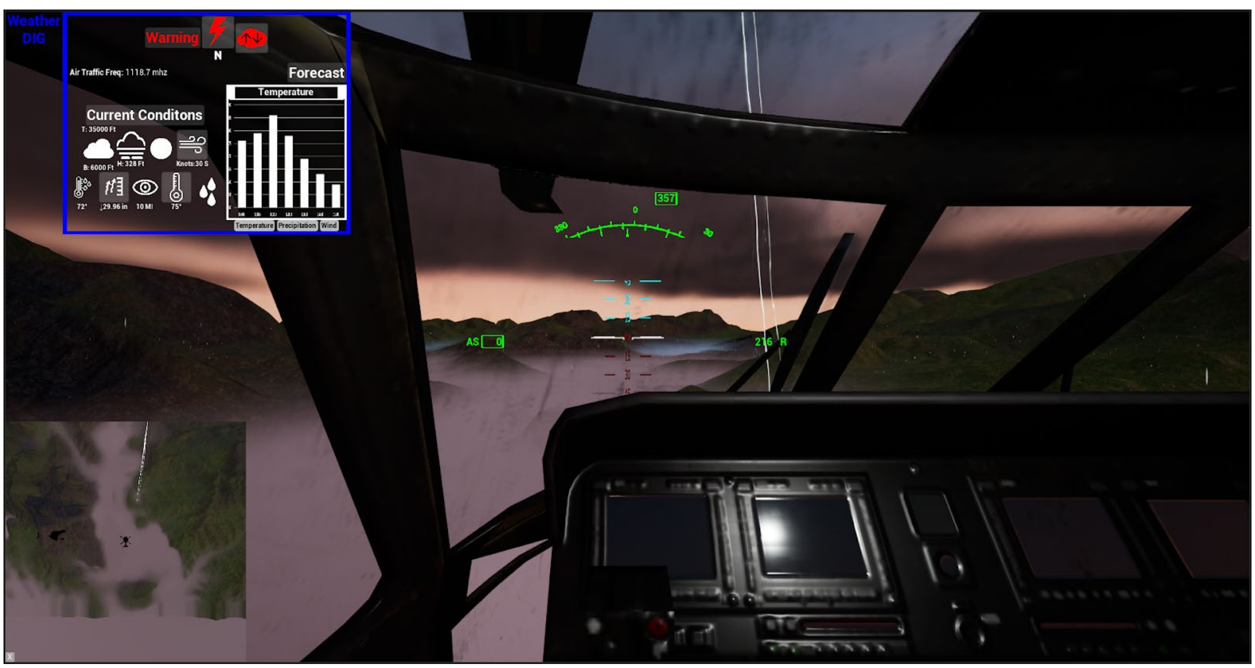

Figure 2. Simulated flight environment

2.2.1. Current Conditions

The current conditions component is displayed using a combination of icons and alphanumeric text, referred to as symbology. The conditions displayed in the simulation are shown in Figure 3. It includes all current and ongoing weather information (cloud cover and ceiling, precipitation, visibility, wind speed/direction, fog, air pressure, temperature, and dewpoint) and, if applicable, the units for each. The displayed symbology for cloud type, cloud cover, and precipitation are designed to vary by what is present in the environment; the full set of possible icons for cloud and precipitation types are in Figure 4.

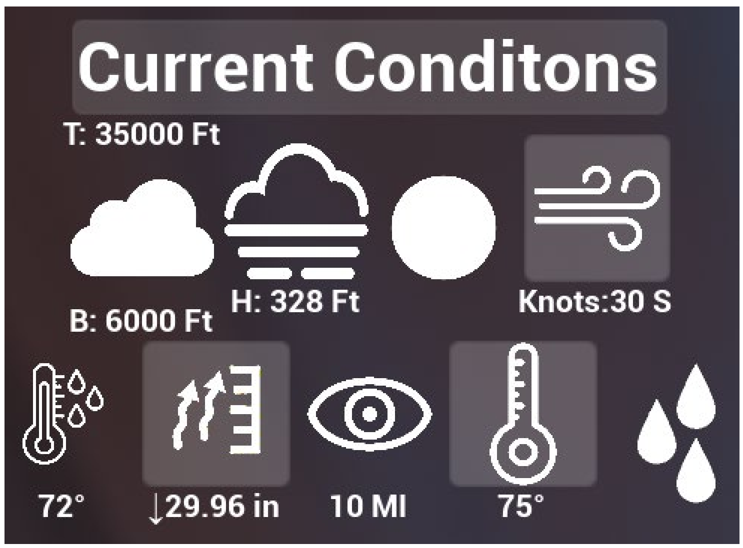

Figure 3. Current conditions component

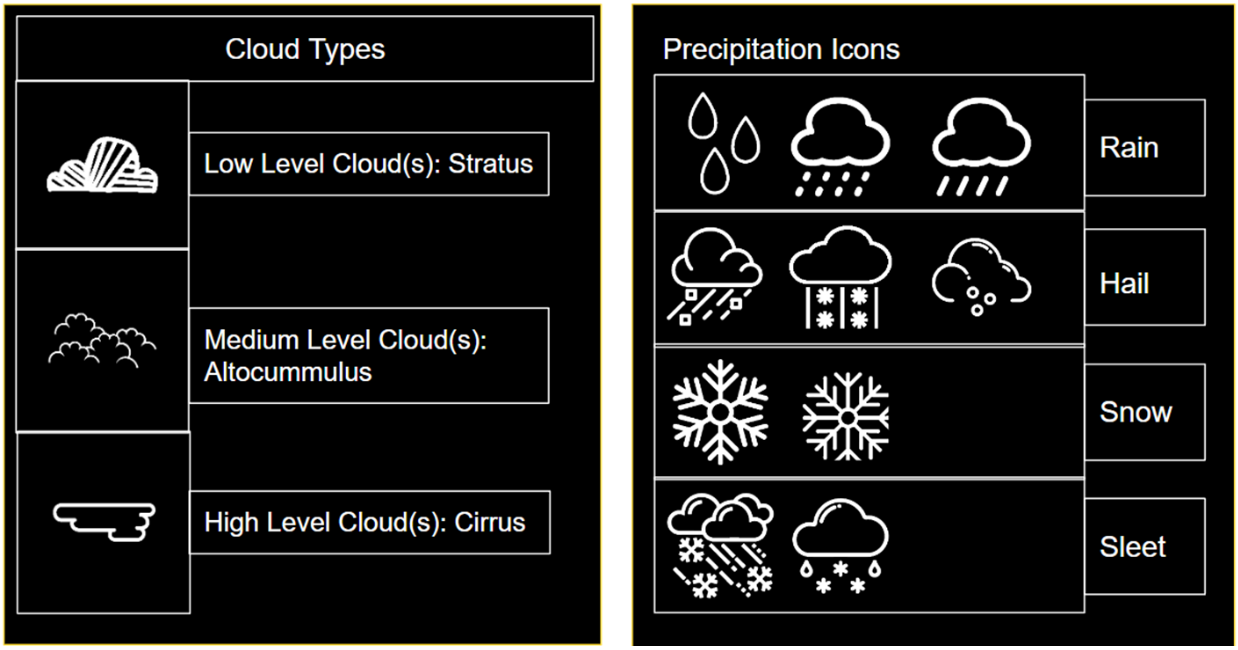

Figure 4. **Icons for cloud and precipitation types**

2.2.2. Advisory/Alerts

The advisory/alert component, shown in Figure 5, is displayed with color-coded symbology to indicate the level of severity of a specified weather phenomenon. A yellow icon designates a weather warning and indicates the operator should proceed with caution. A red icon designates a weather threat and suggests that immediate action be taken. Only lightning and a storm cell warning were chosen for the simulation to create a realistic environment; the full set of advisories and alerts is shown in Figure 6.

Figure 5. **Advisory/alert component**

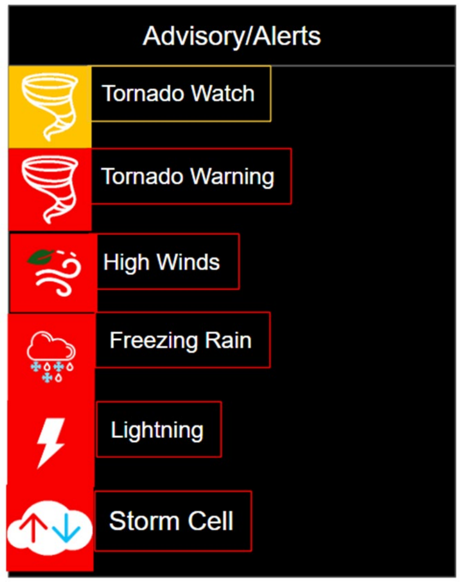

Figure 6. Symbology for advisory/alert types

2.2.3. Forecasts

The forecast component in Figure 7 displays the anticipated weather conditions for the pilot's route in the form of a bar graph by displaying the selected conditions at 1-h intervals. The operator can toggle between temperature, chance of precipitation, and wind-speed forecasts by using the buttons shown at the bottom of the component.

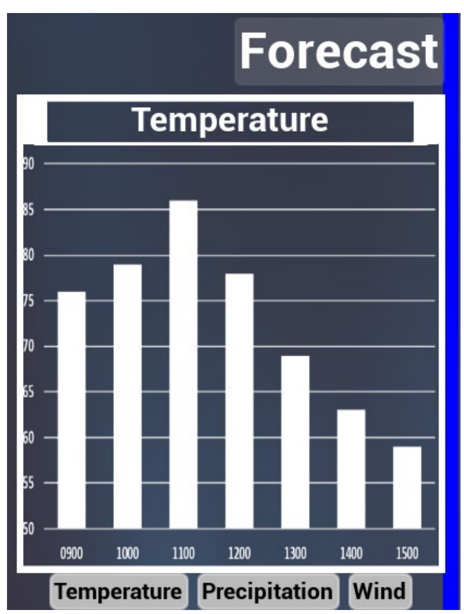

Figure 7. Forecast component

2.2.4. Minimap

The baseline for the minimap is depicted in Figure 8 and includes the local terrain with the black ownship icon in the middle. Six weather modes were designed to overlay on the minimap (fog, lightning, storm cells, temperature, air pressure, and wind) to display nearby weather occurrences with respect to the aircraft position, shown in Figure 9.

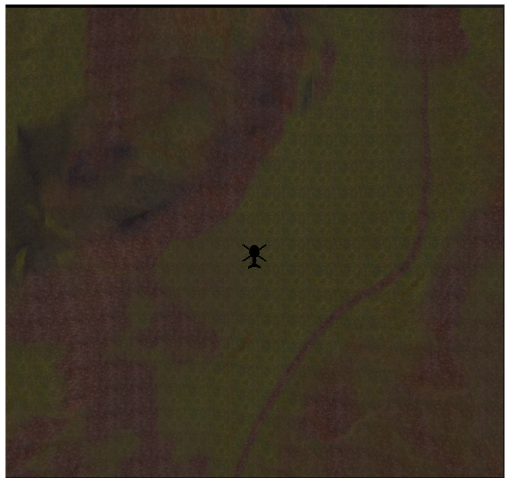

Figure 8. Minimap display

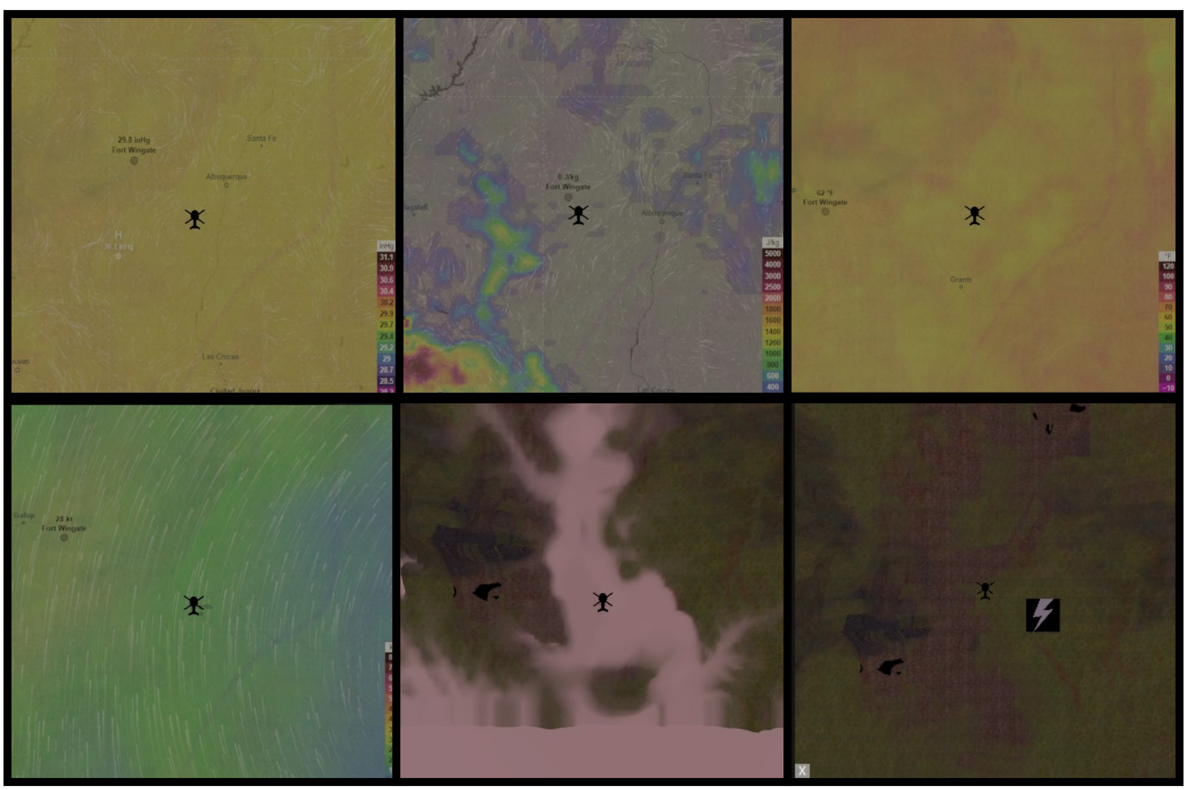

Figure 9. Minimap overlay modes: air pressure (upper left), storm cells (upper center), temperature (upper right), wind (lower left), fog (lower center), and lightning (lower right)

2.3. Questionnaires

2.3.1. Usability

A usability questionnaire was created based on the Usability Metric for User Experience (UMUX; Finstad, 2010), the shorter UMUX-Lite, and the System Usability Scale (SUS; Brooke, 2013). Additionally, custom items were created to address the usability of the weather DIG. The usability questionnaire consisted of nine items, rated on a 7-point Likert scale, with some items worded positively and some worded negatively (Appendix A, Figure A-2). In addition to the usability ratings, the questionnaire included two open-ended questions allowing the participant to comment on needed improvements to the weather DIG and any additional comments.

2.3.2. Situational Awareness

The Situational Awareness Rating Technique (SART; Taylor, 1990) questionnaire was used in the study to assess participant situational awareness. The SART questionnaire consists of 10 questions rated on a 7-point scale, with 1 being the lowest and 7 the highest (Appendix A, Figure A-3). The SART divides questions into three components: attentional demand (instability, variability, complexity), attentional supply (arousal, spare mental capacity, concentration, attention division), and understanding information (quantity, information quality, familiarity). The ratings were combined to calculate the participant's situational awareness using the formula situation awareness = understanding – (demand – supply). This composite situational awareness score was then normalized using a linear transformation to fit a scale of 0–100.

2.3.3. Design Preference

A custom design preference questionnaire was constructed to determine preferred design, icons, and the relevant information necessary for each of the three main weather DIG components (current conditions, advisory/alerts, and forecasts). Participants were presented with a list of weather information and rated the importance of each on a 7-point Likert-type scale, where 1 = very unimportant and 7 = very important (Appendix A, Figure A-4). Additionally, the design preference questionnaire solicited open-ended comments regarding how the weather information would be best displayed and if the participant thought there was any missing information (Appendix A, Figure A-5).

2.4. Study Procedures

The user-centered design sessions were conducted virtually using the Army 365 platform, allowing researchers to screen share and communicate verbally with the participants. Upon arrival, each participant was given an overview presentation including the purpose of the study and the weather DIG design, including the details and possible symbology for each component and their functionality and behavior. After the overview, participants were shown a simulated flight scenario and researchers explained the weather DIG in context.

The scenario consisted of a simple route from point A to point B, starting in a hover above fog with a storm to the right of the aircraft. The aircraft takes off and leaves the fog, escaping the storm, and landing in a nearby field.

Participants gave verbal comments on the weather DIG during and immediately after the scenario. Researchers summarized the participant comments in their notes. After the simulation, the demographics, usability, situational awareness, and design preferences questionnaires were administered.

3. RESULTS AND DISCUSSION

Descriptive statistics were computed for the questionnaire data collected, and participant comments were aggregated. Higher values on the means shown in the figures indicate higher (better) usability, situational awareness, and importance.

3.1. Usability

Figure 10 illustrates the mean usability ratings by questionnaire item. The overall mean usability rating was computed by averaging the nine items using reverse scoring for negatively worded items. The mean usability rating was 5.8 (SD = 1.9). Of the usability questionnaire items, Item 4, which asked if the DIG was too cluttered, had the lowest mean rating. Two of five participants indicated that the DIG was in fact too cluttered.

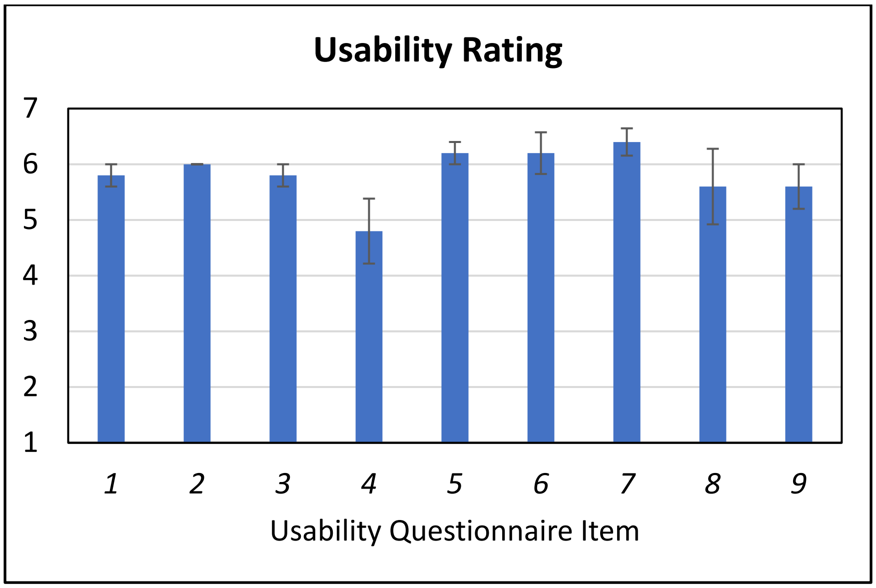

Figure 10. Mean usability ratings (error bars represent the standard error of the mean)

3.2. Situational Awareness

Figure 11 illustrates the composite situational awareness score, which was 59.3 (SD = 33.5). This indicates a fairly poor level of situational awareness for the scenario. One of the five participants had a very low composite situational awareness score (1.7). The mean composite situational awareness score without this single participant would be 73.8.

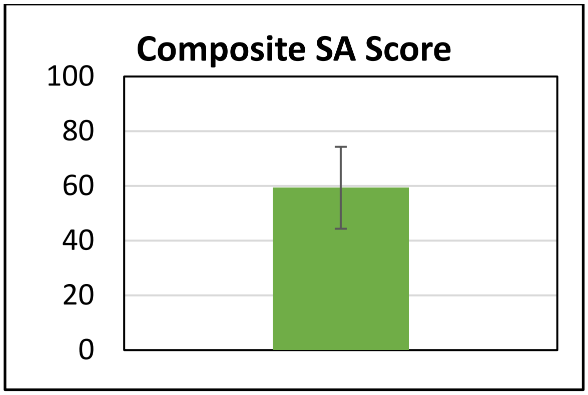

Figure 11. Composite situational awareness score (error bars represent the standard error of the mean)

3.3. Design Preference

Mean importance ratings for the three components of the weather DIG (Figure 12) were compared. Ratings for the advisory/alerts component (M = 6.5, SD = 0.73) were higher than those of the current conditions (M = 5.7, SD = 1.09) and forecast component (M = 5.8, SD = 0.77). These results suggest that alerts aid the most in a pilot's decision-making process. It aligns with participant comments that recommended to include a magnitude for applicable weather events (e.g., lightning in the advisory/alerts component).

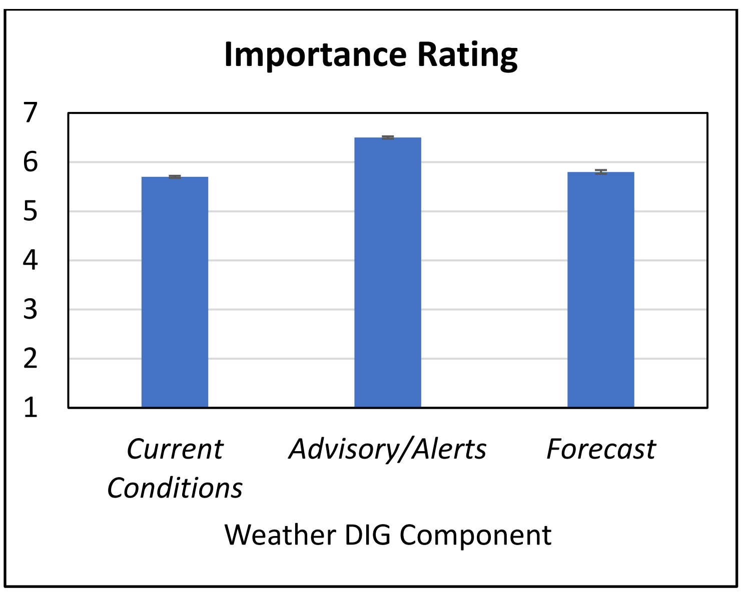

Figure 12. Mean response by DIG component (error bars represent the standard error of the mean)

Open-ended participant comments that could result in a potential design change are listed in the following, organized by each weather DIG component.

3.3.1. Current Conditions

- Give the time of day for sunset and sunrise
- Add the moon phases
- Instead of the icon disappearing instantly, dim it out slowly
- The wind-speed barb would be more useful than the wind icon
- Combine temperature and dew point together
- Represent headwinds and tailwinds
- Current conditions for different altitudes
- Add density altitude
- Specify the amount of rain coming down (e.g., drizzling, downpour)
- Make current conditions larger
- Label the icons and make the labels decluttered; abbreviations would be fine
- Space out the current conditions more; make the forecast smaller
- Color code the current conditions
- Show the conditions for the departure/enroute/destination phases of flight

3.3.2. Advisory/Alert

- Add high and low temperature warnings
- Forecast
- Use a static number instead of a bar graph
- Forecast should include location-based weather (departure/enroute/destination)

3.3.3. Minimap

- Show the distance away from the lightning strike
- Would like to use the minimap to check the weather features at different altitudes
- Would like to zoom in, zoom out, and pan for each mode
- Add distance in kilometers
- Add a visibility mode (at different altitudes)

These suggestions should be integrated into the next phase of the user-centered design process and re-evaluated from there.

4. CONCLUSION

The current study was conducted to obtain feedback from the Army aviation user community on the development of a dynamic infographic for weather. Potential use for said DIG could be in a heads-up display or another aircraft interface depending on the Army's needs. Future work should include further user-centered design iterations that address the participant comments. Additional future research could compare usability and situation awareness ratings with the weather DIG versus traditional methods of accessing weather data. The data described here are only the first observations but demonstrated a viable conceptual design for weather information and laid a methodological framework for additional research.

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Appendix A – Questionnaires

A.1 Demographics Questionnaire

Weather Dynamic Infographic – Demographic Questionnaire

Please provide the following demographic Information:

Age: ______________________________

Gender: ______________________________

Rank: ______________________________

Time in Service: ______________________________

Total U.S. Army Flight Hours (approximately): ______________________________

Overview: The purpose of the Weather Dynamic Infographic is to aid in pilot's awareness of current and future weather conditions while en route. The feedback will be summarized and reported back for potential improvements to the system. We appreciate your open and honest feedback.

Figure A-1. Demographics questionnaire

A.2 Usability Questionnaire

Weather Dynamic Infographic – Usability Questionnaire

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
1. The weather DIG meets my requirements.	1	2	3	4	5	6	7
2. Using the weather DIG was a frustrating experience.	1	2	3	4	5	6	7
3. The weather DIG is easy to use.	1	2	3	4	5	6	7
4. The weather DIG is too cluttered.	1	2	3	4	5	6	7
5. The weather DIG is unnecessarily complex.	1	2	3	4	5	6	7
6. The auto de-clutter feature was essential.	1	2	3	4	5	6	7
7. I would like to use the weather DIG when flying.	1	2	3	4	5	6	7
8. I felt very confident using the weather DIG.	1	2	3	4	5	6	7
9. Overall, I was satisfied with the weather DIG shown to me today.	1	2	3	4	5	6	7

1. If you could improve any features on the weather DIG, what would you change and why?

____
____
____
____
____
____
____
____

2. Please make any additional comments here regarding the weather DIG.

____
____
____
____
____
____
____
____

Figure A-2. Usability questionnaire

A.3 Situational Awareness Questionnaire

Weather Dynamic Infographic – Situational Awareness Questionnaire

	Low						High
1. Instability – How changeable is the situation? (1: Stable and straightforward, 7: Changing suddenly)	1	2	3	4	5	6	7
2. Variability – How many variables are changing within the situation? **(**1: Very few variables changing, 7: A large number of factors varying**)**	1	2	3	4	5	6	7
3. Complexity – How complicated is the situation? **(**1: Simple and straightforward, 7: Complex with many interrelated components**)**	1	2	3	4	5	6	7
4. Arousal – How aroused/focused are you in the situation? **(**1: A low degree of alertness, 7: Alert and ready for activity**)**	1	2	3	4	5	6	7
5. Spare Mental Capacity – How much mental capacity do you have to spare in the situation? **(**1: Nothing to spare at all, 7: Sufficient to attend to many variables**)**	1	2	3	4	5	6	7
6. Concentration – How much are you concentrating on the situation? **(**1: Focusing on only one aspect, 7: Concentrating on many aspects of the situation**)**	1	2	3	4	5	6	7
7. Attention Division – How much of your attention is divided in the situation? **(**1: Focusing on only one, 7: Concentrating on many aspects of the situation**)**	1	2	3	4	5	6	7
8. Information Quantity – How much information have you received and understood about the situation? **(**1: Very little, 7: A great deal of knowledge**)**	1	2	3	4	5	6	7
9. Information Quality – How good is the information that you have access to and have been using? **(**1: Difficult to get required operating parameters/symptoms, 7: Required operating parameters/symptoms are adequately supplied**)**	1	2	3	4	5	6	7
10. Familiarity – How familiar are you with the situation? **(**1: New situation, 7: A great deal of relevant experience**)**	1	2	3	4	5	6	7

Figure A-3. Situational awareness questionnaire

A.4 Design Preference Questionnaire

Weather Dynamic Infographic – Design Preference Questionnaire

Below is a list of features that are part of the Weather Dynamic Infographic.

How important is each feature to you?

	Very Unimportant	Unimportant	Somewhat Unimportant	Neutral	Somewhat Important	Important	Very Important
Current Conditions							
1. Cloud Ceiling	1	2	3	4	5	6	7
2. Cloud Coverage	1	2	3	4	5	6	7
3. Cloud Types	1	2	3	4	5	6	7
4. Fog Height	1	2	3	4	5	6	7
5. Visibility	1	2	3	4	5	6	7
6. Air Pressure	1	2	3	4	5	6	7
7. Dew Point	1	2	3	4	5	6	7
8. Temperature	1	2	3	4	5	6	7
9. Wind Speed/Direction	1	2	3	4	5	6	7
10. Lightning	1	2	3	4	5	6	7
11. Precipitation	1	2	3	4	5	6	7
Advisory/Alerts							
12. High Winds	1	2	3	4	5	6	7
13. Storm Cells	1	2	3	4	5	6	7
14. Pressure Front	1	2	3	4	5	6	7
15. Freezing Precipitation	1	2	3	4	5	6	7
16. Lightning	1	2	3	4	5	6	7
17. Bad Visibility – IFR Conditions	1	2	3	4	5	6	7
Forecasts							
18. Precipitation	1	2	3	4	5	6	7
19. Wind Speed	1	2	3	4	5	6	7
20. Temperature	1	2	3	4	5	6	7
21. Air Pressure	1	2	3	4	5	6	7

Figure A-4. Design preference questionnaire (information importance)

Weather Dynamic Infographic – Design Preference Interview

Current Conditions Component

- What additional information would you need to discriminate weather-related information quickly and easily?
- Are the icons/symbols used comprehensive to the weather scenarios that could occur?
- Is this information best represented with symbology or alphanumeric?
- Do you have any further suggestions regarding the current conditions component of the weather DIG?

Advisory/ Alerts Component

- What additional information would you need to discriminate weather-related information quickly and easily?
- Are the icons/symbols used comprehensive to the weather scenarios that could occur?
- Is this information best represented with symbology or alphanumeric?
- Do you have any further suggestions regarding the advisory/alerts component of the weather DIG?

Forecast Component

- What additional information would you need to discriminate weather-related information quickly and easily?
- Is the data best represented by bar graphs? Why or why not?
- Do you have any further suggestions regarding the forecast component of the weather DIG?

Figure A-5. Design preference questionnaire (participant interview)

LIST OF ACRONYMS

DAC	DEVCOM Analysis Center
DEVCOM	U.S. Army Combat Capabilities Development Command
DIG	dynamic infographic
DOD	U.S. Department of Defense
FAA	U.S. Federal Aviation Administration
GPS	Global Positioning System
M	mean
SART	Situational Awareness Rating Technique
SD	standard deviation
SUS	System Usability Scale
UMUX	Usability Metric for User Experience

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