

DOT/FAA/TC-21/28

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Visual 3D Weather Display for Preflight Planning

May 2022

Final report



U.S. Department of Transportation
Federal Aviation Administration

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Form DOT F 1700.7 (8-72)

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1. Report No. DOT/FAA/TC-21/28		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Visual 3D Weather Display for Preflight Planning				5. Report Date May 17, 2022	
				6. Performing Organization Code	
7. Author(s) Ethan Krimins				8. Performing Organization Report No.	
9. Performing Organization Name and Address Flightprofiler 9370 Fields Ertel Road #498032 Cincinnati, Ohio 45249				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. DTFACT-16-R-00054	
12. Sponsoring Agency Name and Address Federal Aviation Administration 901 Locust Street Kansas City, MO 64106-2641				13. Type of Report and Period Covered Final Report	
				14. Sponsoring Agency Code AIR-714	
15. Supplementary Notes The sponsor for this project was David G. Sizoo, FAA Flight Test Pilot. The project was initiated to fill a gap in the preflight planning tools that pilots have. Many great weather products exist from the aviation weather center and aviation digital data services. However, a 3D tool that visually depicts weather in relation to a flight path has not been perfected and made readily available for free to all pilots. The goal of this project was to enhance tools available to pilots for preflight planning. We hope the Profiler code will be hosted on a server (such as the Aviation Weather Center) that all pilots can access at no cost. The profiler prototype could evolve after incorporating user feedback to improve the graphical user interface. Additional use cases for preflight planning exist with Unmanned Aircraft Systems (UAS) and Advanced Air Mobility (AAM) to depict Low Altitude Weather. The Air Force Agility Prime Project is leveraging the initial work done under this contract to adapt it to both UAS and AAM missions. The Purdue Profiler project was also highlighted at the Nov 11, 2021 Ohio Advanced Air Mobility Showcase. The Federal Aviation Administration William J. Hughes Technical Center Aviation Research Division COR was Nicole Saiauskie.					
16. Abstract Most General Aviation (GA) pilots cannot accurately measure visibility in flight and therefore adhering to FAA regulations for Visual Flight Rules (e.g., 3 miles visibility) is often unachievable and unrealistic. This difficulty is not just technological, pilots without meteorological expertise struggle in pre-flight planning to interpret complex, non-visual (code & symbol) weather data needed to estimate visibility. The objective of this project was to solve these problems by enabling pilots to measure distance to weather in preflight planning and therefore quantify FAA regulatory criteria, and to present weather in a simple visual format. The technology developed under this Broad Agency Announcement (BAA) achieved this by visually displaying weather for preflight planning in relation to a planned trajectory. It may help pilots make go/no-go decisions and reduce inadvertent flight into instrument meteorological conditions (IMC). The technology is able to present accurate 3D weather for preflight planning. This capability directly translates to improved flight safety and situational awareness, including: 1) identifying when/where weather impacts a planned flight, 2) visually presenting complex atmospheric conditions, 3) illustrating flight choices with respect to weather, 4) enabling the pilot to plan for likely weather conditions, and 5) identifying safer routes and/or egress corridors.					
17. Key Words Weather, meteorology, flight planning, Instrument Conditions, IMC, VMC, forecasting, computer, technology, coding, programming, augmented reality, virtual reality, 3D, CFIT, LOC, go/no go, flight safety			18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov .		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 16	
				22. Price	

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Acronyms

Acronym	Definition
3D	Three Dimensional
ATC	Air Traffic Control
BAA	Broad Agency Announcement
CFIT	Controlled Flight into Terrain
FAA	Federal Aviation Administration
HPC	High Performance Computer
HRRR	High-Resolution Rapid Refresh [Weather Data]
IFR	Instrument Flight Rules
IMC	Instrument Metrological Conditions
LOC	Loss of Control
NDFD	National Digital Forecast Database [Weather Data]
NOAA	National Oceanic and Atmospheric Administration
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	Very High Frequency Omnidirectional Ranging

Executive summary

The technology developed under this Broad Agency Announcement (BAA) displays weather graphically in 3D and in relation to a planned flight plan. It may help pilots make go/no-go decisions. It may reduce unintentional flight into instrument meteorological conditions (IMC) by allowing users to dynamically alter a planned flight path to maintain visual flight rules (VFR) cloud clearance and visibility within airspace constraints.

This technology utilizes multiple data sources in a real-time, 3-axis, meteorological visualization. It allows for the ability to filter specific weather factors and isolate atmospheric conditions important to the user and/or pilot.

The technology includes the following pre-flight planning capabilities:

- Flight viewing
- Hazard identification
- Visual meteorological conditions (VMC) & IMC airspace differentiation
- Three different visualization perspectives (cockpit, exocentric and atmospheric/navigation)

The benefits of this technology are focused on reducing controlled flight into terrain (CFIT) and loss of control (LOC), which is achieved via the following:

- Improving aeronautical decision making by identifying when/where weather impacts a flight
- Decreasing errors by lessening the need for pilots to be experts in meteorology
- Assisting preflight planning by illustrating flight choices with respect to weather
- Reducing in-flight workload by enabling the pilot to plan for likely weather conditions
- Aiding in-flight situational awareness
- Illustrating flight proximity to safer routes and/or egress corridors

1 Introduction

Many studies have correlated CFIT and LOC accident rates with unintentional VFR flight into IMC conditions. This technology was developed to reduce these accidents. The technology is a collaboration of programmers, scientists, researchers, meteorologists, and pilots. The technology is operational and fully functional.

2 Weather data

Raw weather data supplied by both public, such as the National Oceanic and Atmospheric Administration (NOAA), and private sources provides the metrological input that this technology is based upon. NOAA's High-Resolution Rapid Refresh (HRRR) and National Digital Forecast Database (NDFD) weather data have both been utilized for meteorological input (see Figure 1), but there is also the ability to incorporate other raw or modeled data.

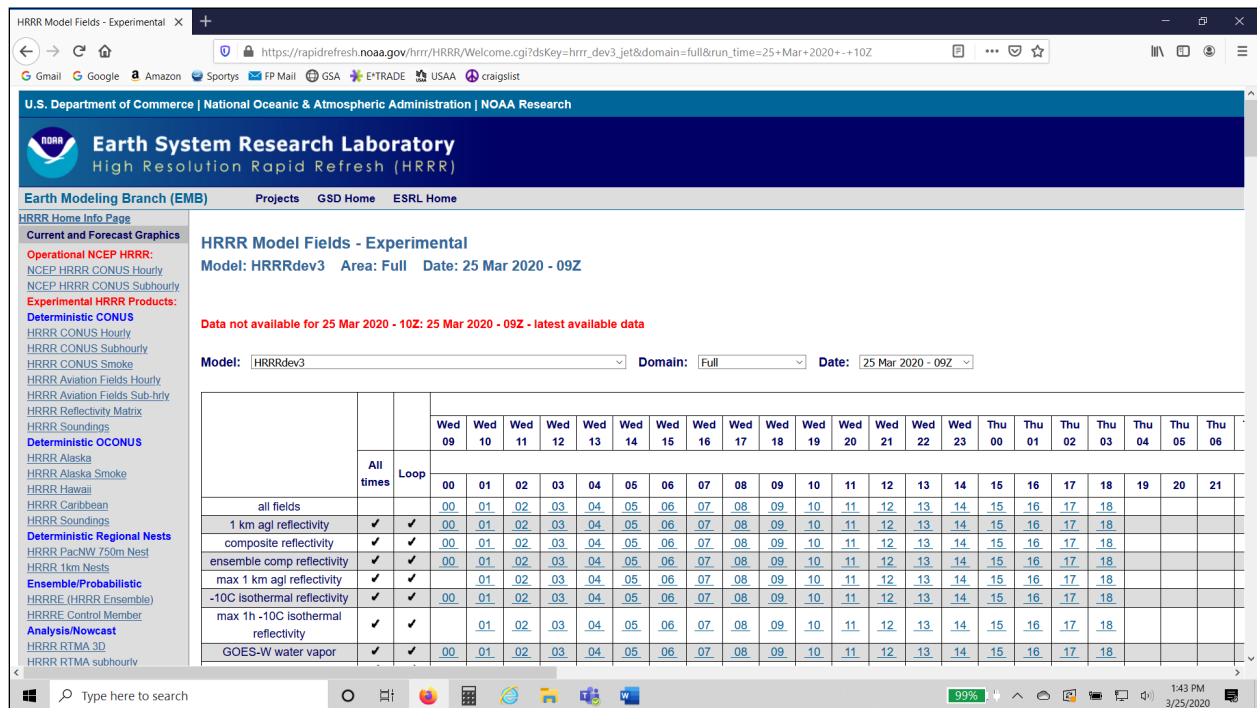


Figure 1. HRRR weather data

The vast amount of potential weather data overwhelms all but the most robust high performance computers (HPCs); however, this technology requires an output to be usable on average or typical computers. Therefore, proprietary coding developed during this BAA has focused on the

optimization of packetized data for live weather representation. These optimization techniques have enabled the deployment of this dynamic output on laptop computers and mobile devices.

Optimization reduces processing load by minimizing visual calculations and bundling areas of identical data. Figure 2 illustrates how individual cells build to form an area of clouds.

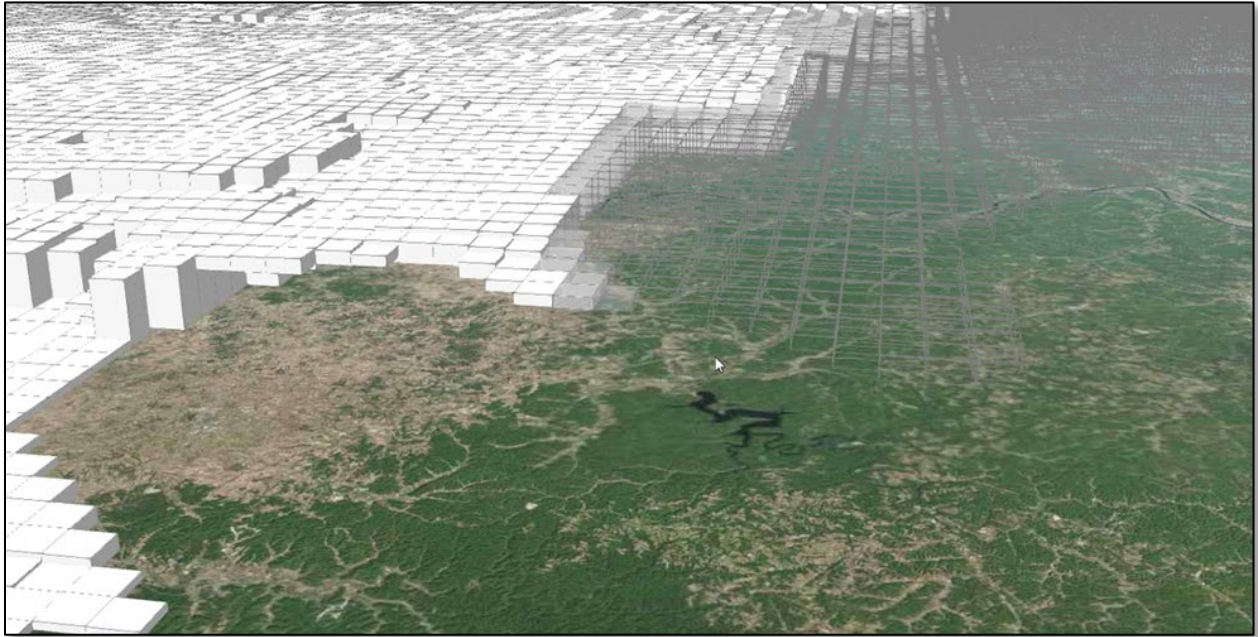


Figure 2. Cube weather creation

The 3D output includes the ability to show cloud layering and dimensions. In Figure 3, thinner cirrus type clouds are above the thicker cumulous while several unique shaped clouds are nearby.

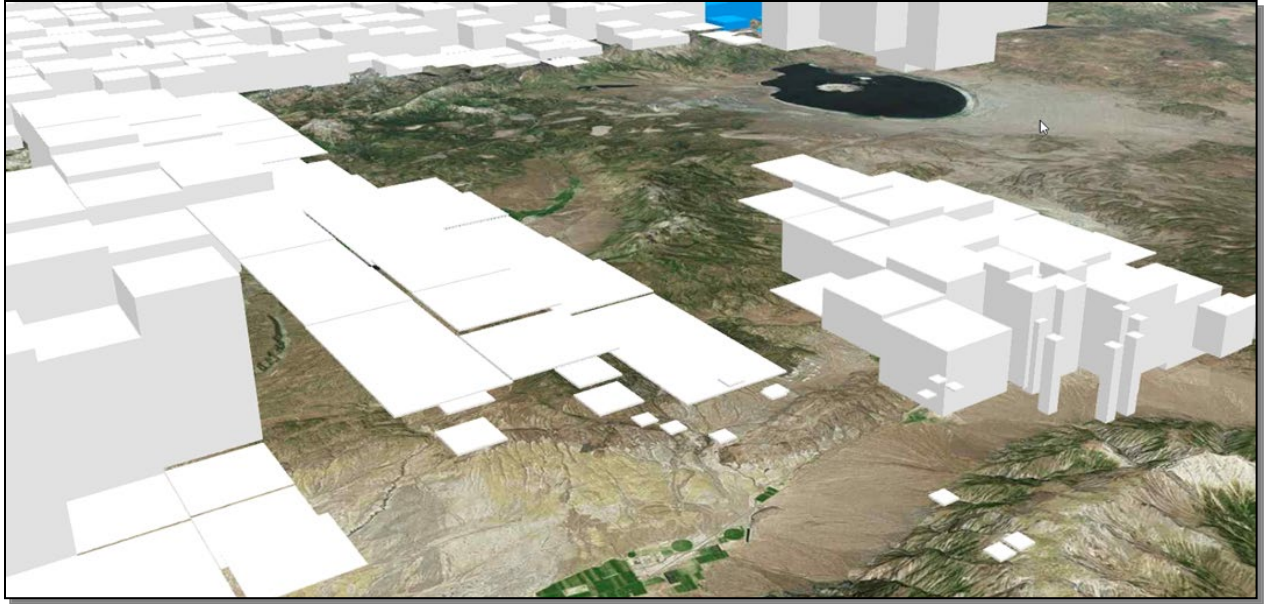


Figure 3. Cloud layering & sizing

Modeled weather data has the ability to generate forecasts, and in those cases this technology can dynamically display forecasts in addition to real-time visual presentations. Similar to how 2D weather can be dynamically displayed to illustrate a forecast, our output is similarly able to display a 3D forecast. Figure 4 shows a 3D visual of forecast data.

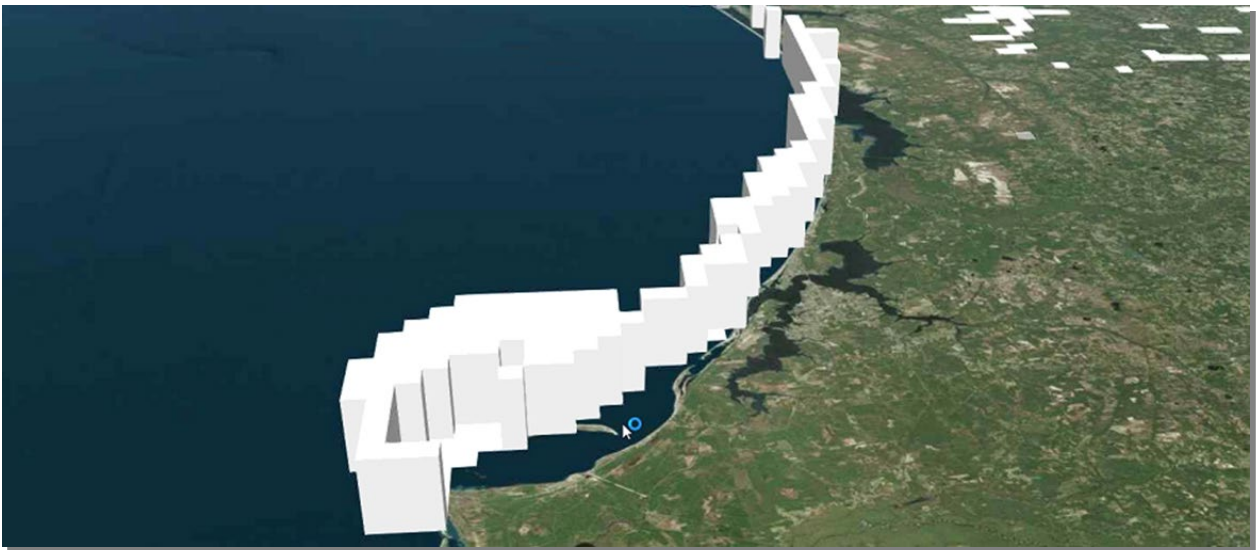


Figure 4. Forecast of lakefront instrument flight rules (IFR) conditions

3 IMC & VMC delineation

A primary objective was to identify IMC and therefore most project coding centered on cloud visualization. However, the same coding enabled identification of other atmospheric areas. The result is a 3D creation of the atmospheric environment where individual meteorological phenomena can be discretely identified or highlighted. Colors in Figure 5 indicate precipitation.

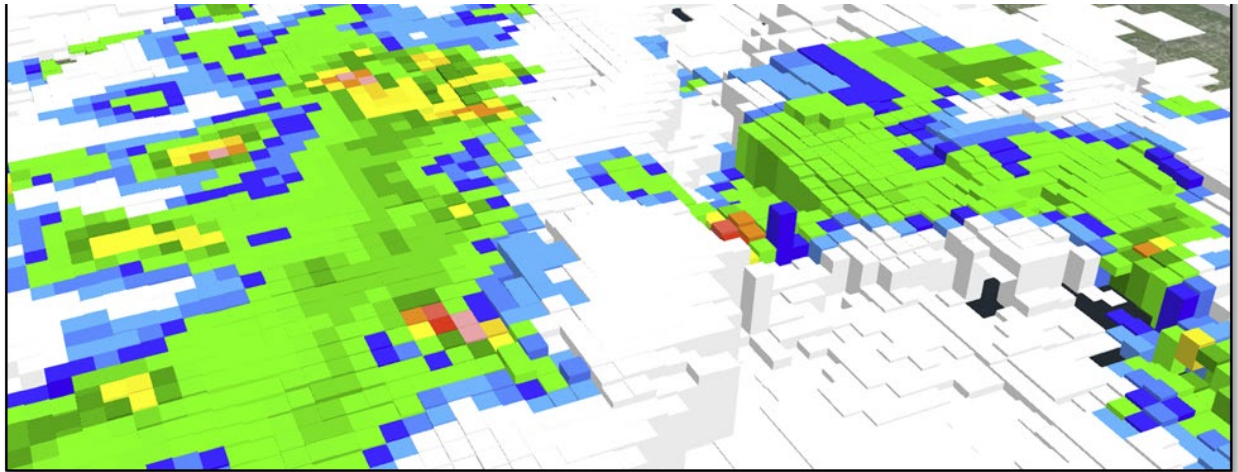


Figure 5. Precipitation

4 Preflight planning

Integrated within the 3D weather technology is the ability to depict flight paths and waypoints. A solid blue flight path line is utilized for VMC and a dashed red line for any IMC flight paths (see Figure 6).

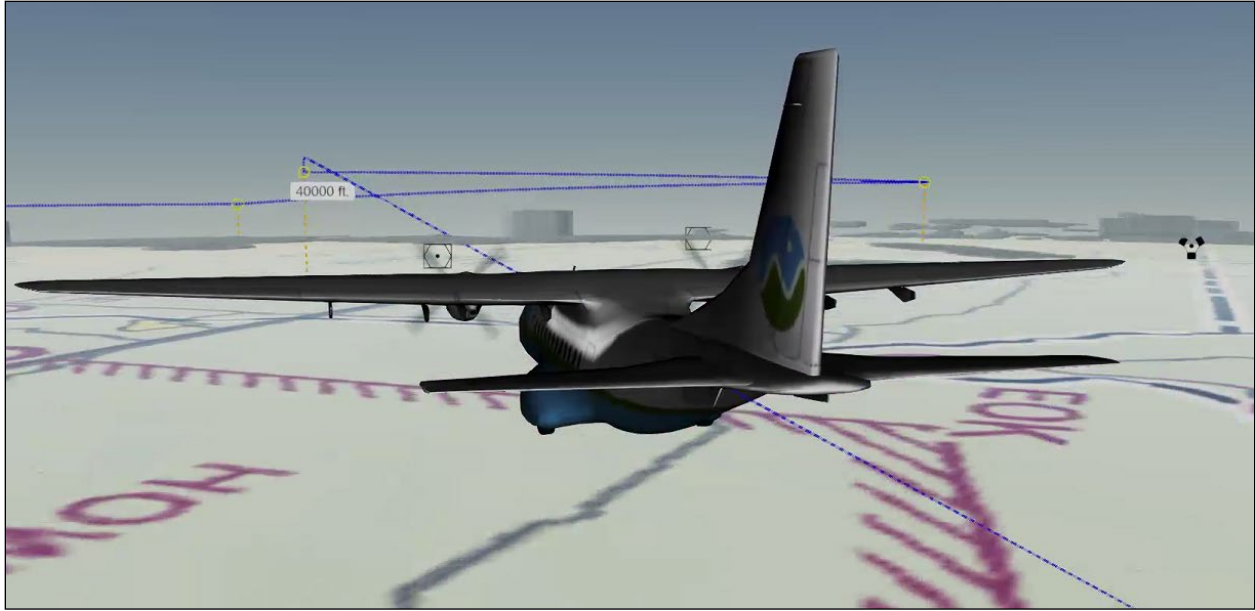


Figure 6. Solid blue VFR flight path over sectional chart details

IMC can be isolated along a flight path, which is illustrated as red boxes (see Figure 7).

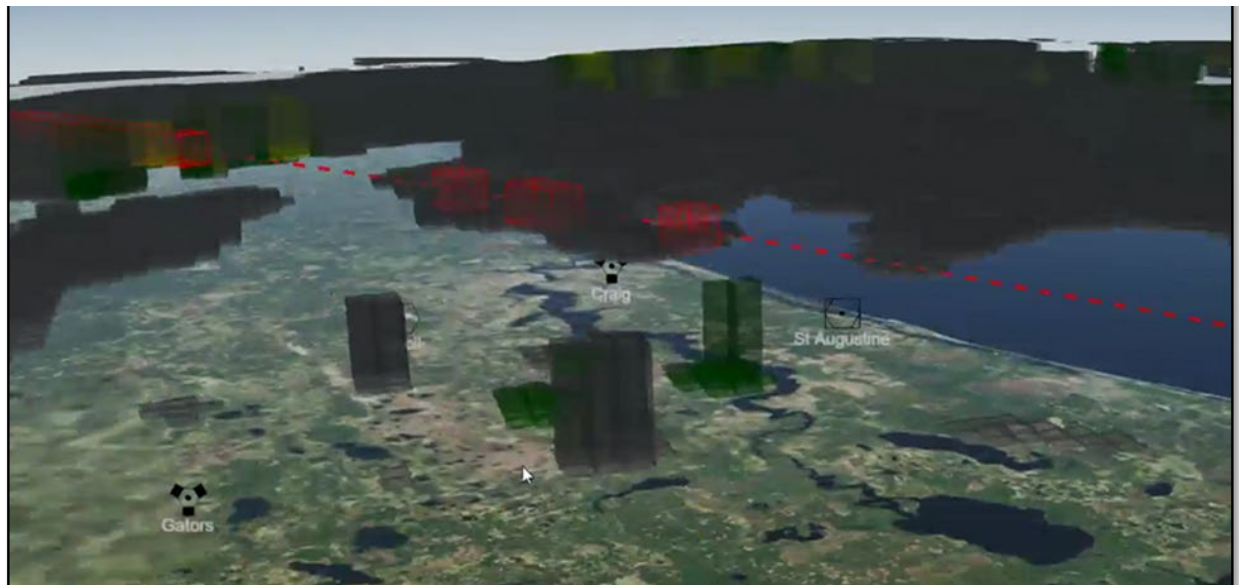


Figure 7. Flight path with boxes identifying flight path/IFR intersection

In weather where egress routes may not be available, the output (see Figure 8) can illustrate where altitude changes identify flight path emergence from IMC.



Figure 8. Flight path emerging from IFR

We also created Class B and Class C airspace where weather conditions may alter FAA regulations. Figure 9 shows the airspace around Kansas City.

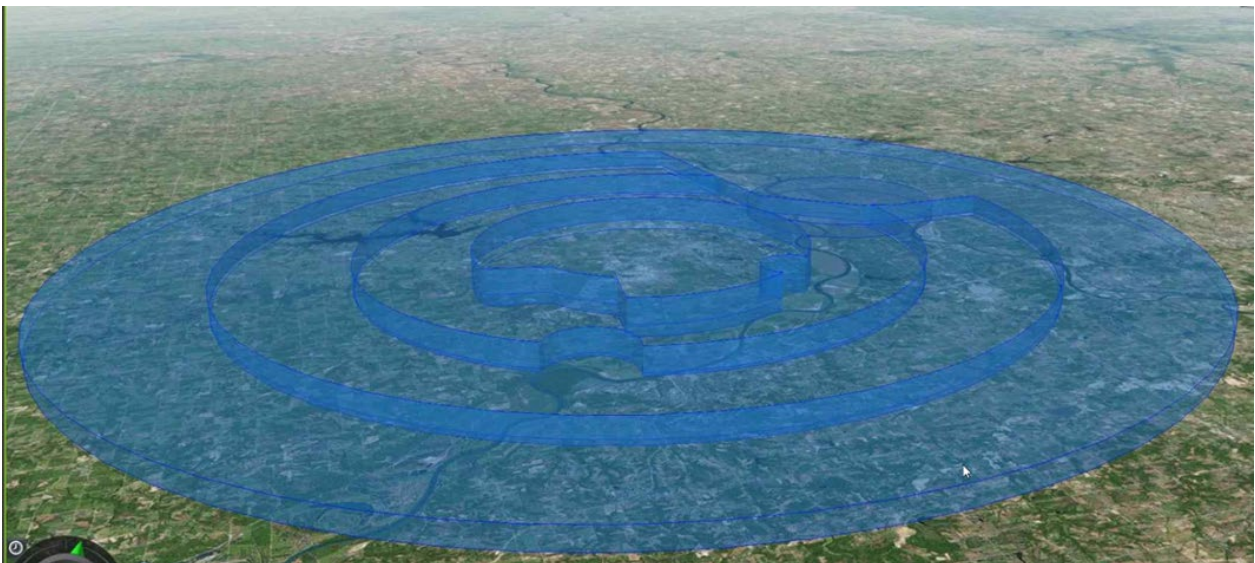


Figure 9. Kansas City airspace

User perspectives include cockpit-centric, flight-following, and a top-down view. The cockpit centric high-resolution pilot field of view (± 45 degrees) enables the preflight preparation of

virtually flying the actual flight plan in the current or forecasted weather. This includes the ability to stop, start, fast forward, and reverse along their flight plan (see Figure 10). Additionally, the user/pilot can elect changes to altitude to plan flights above/under or around the tops or bottoms of clouds.

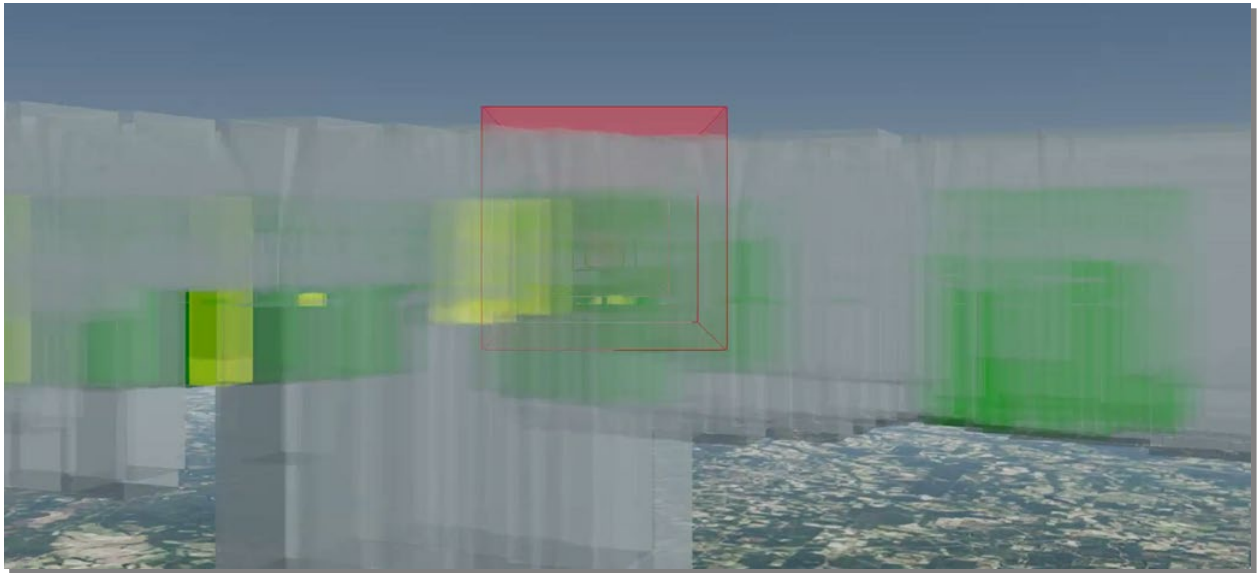


Figure 10. Cockpit view of flight path (red box) about to enter IMC

Figure 11 is an illustration of the exocentric perspective just prior to the aircraft entering IMC.

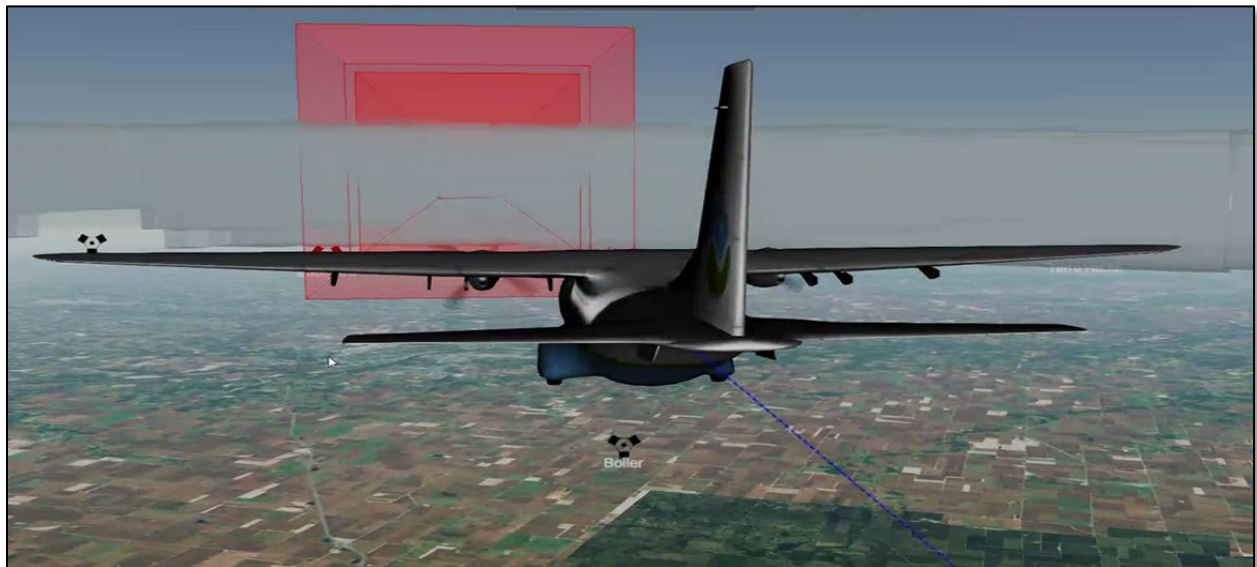


Figure 11. Aircraft prior to entering IMC

Users are able to enter multiple waypoints (airports, VORs, or user-selected points), change altitude, and adjust their flight plan in a simple and intuitive user interface. Figure 12 shows a user-defined waypoint just prior to entering IMC.



Figure 12. User-defined waypoint prior to entering IMC

5 Value

The value of the technology is to provide a previously unavailable ability for pilots to understand the atmospheric environment as it exists (in 3D) during the pre-flight planning process. This leads to knowing where VMC and IMC exists and how it impacts the planned flight. The specific advantages of this technology include the following:

- The technology aids preflight planning by illustrating flight choices with respect to the atmospheric environment.
- CFIT & LOC are decreased by lessening the need for pilots to be experts in meteorology.
- In-flight workload is reduced by enabling the pilot to know what is “lurking around the weather corner” and being able to plan for likely weather conditions.
- Pilots and Air Traffic Control (ATC) can accurately determine what are the best egress options, safest routes and other in-flight changes.
- The technology improves a pilot’s aeronautical decision-making by identifying when and where meteorology impacts the flight.

6 Video demonstration

Live demonstrations are available upon request and FAA videos of the technology can be seen at the www.flightprofiler.com website.