Pergamon

Journal of Safety Research 36 (2005) 159 – 169

www.elsevier.com/locate/jsr

www.nsc.org

Work domain analysis for air traffic controller weather displays

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Received 24 August 2004; received in revised form 18 November 2004; accepted 16 March 2005

Abstract

Introduction: Adverse weather conditions have a major impact on National Airspace System (NAS) operations. They create safety hazards for pilots, constrain the usable airspace for air traffic control (ATC), and reduce the overall capacity of the NAS. A system-wide dissemination of weather information to controllers could theoretically improve safety and efficiency. *Problem:* However, it is currently unclear what weather information would be beneficial for tactical operations. Furthermore, no previous research has empirically evaluated optimal presentation designs for ATC weather displays. Ill-designed weather displays can cause safety hazards by presenting redundant information (i.e., by increasing the cognitive load) and display clutter (e.g., by interfering with the visual extraction of traffic data). *Method:* In the present paper, we outline our use of cognitive work analysis (CWA) techniques for the assessment of weather information needs for terminal controllers. *Results:* Specifically, we describe how the CWA modeling tools helped us reveal instances in the terminal domain where weather information is lacking or insufficiently disseminated. We used our CWA results to drive the development of weather display concepts and to set up a high-fidelity simulation capability. *Impact on Industry:* By means of high-fidelity simulations, we can empirically evaluate controller weather information needs in order to propose weather displays for increased aircraft safety and efficiency of terminal operations.

Keywords: Cognitive work analysis; Terminal air traffic control; Information requirements; Display design; Simulation capability

1. Introduction

Adverse weather has a major impact on National Airspace System (NAS) operations. It creates safety hazards for pilots, constrains the usable airspace for air traffic control (ATC), and reduces the overall capacity of the NAS. Adverse weather conditions also increase the workload for all NAS operators.

Adverse weather conditions are also a factor in many aviation accidents. The National Transportation Safety Board (NTSB, 1999a) reports that 23% of major airline and cargo carrier (Part 121) accidents were weather-related during 1999. For commercial air carriers (Scheduled Part 135) the accidents were weather-related in 38%, and for airplanes and helicopters (Nonscheduled Part 135) it was 23% and 47%, respectively. For general aviation (GA),

Abbreviations: ACE-IDS, Automated Surface Observing System Controller Equipment-Information Display System; ASOS, Automated Surface Observing System; ATC, Air Traffic Control; CARTS, Common ARTS Display; CIWS, Corridor Integrated Weather System; CWA, Cognitive Work Analysis; DASI, Digital Altimeter Setting Indicator; DESIREE, Distributed Environment for Simulation, Rapid Engineering, and Experimentation; FAA, Federal Aviation Administration; FSS, Flight Service Station; GA, General Aviation; IDS, Information Display System; ITWS, Integrated Terminal Weather System; MIAWS, Medium-Intensity Airport Weather System; NAS, National Airspace System; RVR, Runway Visual Range; SAWS, Stand Alone Weather Sensors; STARS, Standard Terminal Automation Replacement System; TDWR, Terminal Doppler Weather Radar; VFR, Visual Flight Rules; WSP, Weather Systems Processor.

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doi:10.1016/j.jsr.2005.03.001

weather conditions were a factor in 19% of all accidents (NTSB, 1999b).

One way to reduce the effects of adverse weather on NAS operations is to provide timely and accurate information about weather conditions. For ATC management, weather information can help reduce delays by improving the ability to adjust the flow of traffic around adverse weather areas. Pilots need timely and accurate weather information for flight decisions that impact safety. Controllers need weather information to optimize the use of routes and runways and for improved planning and weather advisories to pilots.

Currently, ATC management and flight dispatchers have access to various sources of advanced weather data (e.g., detailed information about storm cells and their motion). Pilots in well-equipped cockpits also have access to advanced weather information. Controllers, on the other hand, at their workstation, only have access to precipitation data. Depending on the domain (i.e., en route or terminal ATC) other types of information like visibility values and surface weather data might be available.) This disparity has led to an increased interest and raised new questions about the effects of providing advanced weather information to controllers.

First, it is currently unclear what types of weather information could benefit controllers during tactical operations. Second, we know little about the potential human factors issues related to the implementation of weather information on controller displays. Third, we have no prior history and experience of how controllers would use this information tactically. Implementation of weather displays therefore carries with it some degree of risk. Researchers need to identify information requirements and display designs that can mitigate this risk.

The present paper describes an ongoing research project by researchers at the NAS Human Factors Lab on weather information for terminal controllers. At the start of the project, our analysis team reviewed previous research on weather requirements and the use of weather displays by controllers and pilots (Ahlstrom, 2003). The team conducted a cognitive work analysis (CWA; Vicente, 1999) of the terminal domain to assess controllers' weather information needs. In the present paper, we outline our use of CWA techniques and give some examples from our analyses. Specifically, we describe how the CWA modeling tools helped us reveal instances in the terminal domain where weather information is lacking or insufficiently disseminated. We then used the results of our analyses to drive the development of weather display concepts (Ahlstrom, Keen, & Mieskolainen, 2004) and a high-fidelity simulation capability. In the end, our goal is to empirically evaluate controller weather information needs and propose weather displays for increased aircraft safety and efficiency of terminal operations.

1.1. Terminal ATC

In general, the terminal area is centered on a primary airport and extends approximately 40 miles in all directions. The airspace usually extends from the surface up to approximately 10,000 feet. However, the terminal airspace has various dimensions depending on its location and the size and number of airports within its area. Commonly, there are additional smaller airports (e.g., satellite airports) located within the same terminal area. In these situations, there are many different operations occurring at the same time within the terminal area (e.g., taxiing on the airport surface ([coming and going]), aircraft arriving/departing the airport, and aircraft climbing to cruising altitudes and descending from cruising altitudes).

Terminal facilities perform radar operations where air traffic controllers direct aircraft during the departure, descent, and approach phases of flight. Specifically, the terminal controller directs aircraft that are transitioning from the en route phase through to the approach phase into a destination airport located within the terminal airspace (in addition to directing aircraft for departures). The controller ensures that all aircraft entering or departing the airspace are separated at safe distances. Because of the high density of traffic and dynamic aircraft maneuvers, adverse weather conditions greatly affect terminal operations (Collins, 1991).

1.2. Adverse weather phenomena

Thunderstorms are the most significant weather phenomenon that contributes to aviation hazards and flight delays. Among the thunderstorm attributes, we find lightning, tornadoes, heavy rain, hail, turbulence, icing, wind shear, and microburst (Lawson, Angus, & Heymsfield, 1998; Williams et al., 1999). Thunderstorm activity affects the controller by constraining the usable part of the airspace. It also adds to the complexity for the controller because pilots will request deviations and alternate routings.

In-flight icing is predominantly a problem for general aviation (Maynard & Sand, 1999), but it also affects other aircraft operating at altitudes where conditions are favorable for icing. It affects the controller because pilots will request changes in altitude or routes to avoid icing conditions. In-flight icing also constrains the use of parts of the airspace for aircraft that lack deicing systems.

Obstructions to visibility are weather conditions that in some way reduce the pilot's ability to perceive the layout of runways, surrounding terrain, or the position of other aircraft. Also included in this category are restrictions on airport operations that are due to ceilings and visibility below what is required for normal operations. Ceilings below minimums can effectively close an airport or prevent operations of certain aircraft types.

Wind shear and microbursts are convective and non-convective phenomena that include gust fronts and wind shift lines. In the terminal area, these phenomena produce