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A RESPONSE TO HAZARDOUS WEATHER: INTEGRATE WEATHER INFORMATION INTO TRAFFIC FLOW MANAGEMENT

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1. INTRODUCTION

In response to the increase in traffic delays in the late 1990s, the FAA has sought to identify projects that would increase capacity and modernize the FAA traffic management system. Since "weather" is reported to be the cause of over 70% of the system delays, an entire quadrant (25%) of the *Operational Evolution Plan (OEP)* (FAA, 2004) is dedicated to finding solutions to the problem of En Route Severe Weather (Fig. 1). The system response to hazardous weather is a reduction of available resources--airspace capacity in the National Airspace System (NAS). What has been accomplished, and where are we going?

Figure 1 – The structure of the Operational Evolution Plan (FAA, 2004)

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2. BACKGROUND

Over the past several years, investments made in weather products for the en route domain largely rested with the research and development community to improve detection and forecasting of weather hazards. Accomplishments during this period appear substantial, and some tools and systems have actually been transferred into a prototype or operational status. Some examples include:

- ADDS - Aviation Digital Data Service (Internet)
- RTVS - Real Time Verification System to verify convective forecasts
- CCFP - Collaborative Convective Forecast Product to forecast thunderstorms 2/4/6 hours in advance
- NCWF National Convective Weather Forecast to identify and forecast thunderstorms on a national scale 1 hour in advance.
- ITWS - Integrated Terminal Weather System to observe and forecast local thunderstorms using Doppler radar data out to 1 hour in advance.
- CIWS - Corridor Integrated Weather System to observe and forecast thunderstorm activity out to 2 hours in advance over a highly traveled high impact area of the NAS.
- CIP - Current Icing Potential identifies areas and altitudes of hazardous icing conditions.
- GTG - Graphical Turbulence Guidance
- RUC - Rapid Update Cycle weather forecast model now resolves winds and convection down to 20 km in the horizontal.
- WARP - Displays NEXRAD on the DSR controller screen based on a successful implementation at DFW.

3. MOVING FORWARD

With all these new products, can we expect commensurate improvements in safety and management of the NAS? An important part of the answer is the integration—not of the products, but of the application of these products. In the next version of the OEP we will build on what has already been accomplished. The changes proposed in structure and priority are guided and directed by several important benchmark studies and the recommendations of advisory groups:

- The FAA Flight Plan presents the strategic issues that need to be addressed (2005-2009).
- A Mission Need Statement (MNS) for Aviation Weather has been completed (FAA, 2002) and approved by the Joint Science Counsel (JSC). Included in the MNS are 16 topics, of which the first priority is Thunderstorms; the second priority is Icing; the fourth priority is Turbulence and Flight Level Winds.
- A Workshop of the National Research Council (NRC; June 2002) has addressed Weather Forecasting Accuracy for Traffic Flow Management. The report encouraged development and application of objective weather forecast models.
- The Workshops on Air Traffic Management and Decision Support Systems sponsored by AUA-1 and MITRE, NCAR, and MIT/Lincoln Labs. The participants stressed the ultimate objective to integrate weather forecasts into automated traffic management tools---Decision Support Systems. AUA (2003)
- The Aviation Weather Technology Transfer Board (AWTT) Board has defined a process for transferring a subset of weather products form research into operational practice. The Board encourages development of a Concept of Use for weather products.
- The Functional Analysis of Traffic Flow Management--Infrastructure describes the elemental decisions for TFM, including those that use weather forecasts. (FAA, 2002)
- The Weather Application Work Group (WAWG) of the Collaborative Decision Making consortium includes participants from Air Traffic Organization's (ATO) customers, employees, and owners. This group has led the requirements development and improvement recommendations for the CCFP used in the TFM planning process. Additional workgroups are leading the implementation of changes to the traffic management system and procedures.

3.1 OEP System Severe Weather Quadrant (SSW)

The leadership for the OEP Quadrant associated with en route weather issues is the Point of Decision (POD) Jack Kies, Director of System Operations. Other offices of ATO support the POD. The description that follows was proposed for an updated version of V6.0 (Kies, 2004). In particular, the focus was changed to a system emphasis, as indicated in the Quadrant label, System Severe Weather (SSW). The proposed elements are Convection, Flight Level Turbulence, and CWSU Restructuring (Fig. 2).

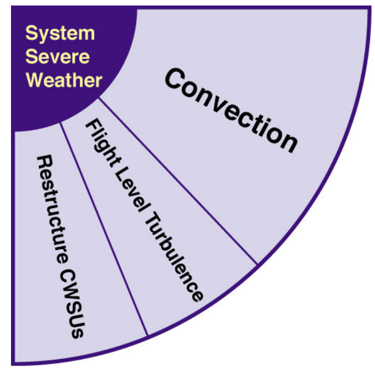

Figure 2 – The proposed structure of the System Severe Weather (SSW) Quadrant of the OEP.

The updated version of the OEP plan is built on a sustained effort over the past 3 years to build a solid foundation of accomplishment. Using the studies and advice (section 3) already cited, the OEP leadership has identified critical gaps in the use of current weather products for traffic flow management. The proposed scope of the SSW Quadrant was been broadened to address the recommended priorities of weather issues, including the use of objective forecast models. To affect real operational change will require a clear *Concept of Operations*, a development of *Best Practices* for improving the utility of weather information, and a renewed commitment to training as demonstrated by a *Training Plan*. Finally, the vehicle for delivering operational change is the integration of weather information into Decision Support Systems (DSSs).

4. Strategies

Disruptions in air traffic caused by hazardous weather are magnified by the lack of understanding of weather information and an intrinsic uncertainty of the forecast. First, there is a *discrepancy* between weather observations and the forecast (i.e. accuracy, precision, consistency and intensity). Secondly, there is a deficiency in the application of TFM strategies that use the weather information to mitigate the impacts on the en-route environment. Under these conditions, therefore, what strategies should we use to bring uncertain weather forecasts into the environment of precise and unambiguous traffic management? Although there are a variety of tactics that are employed to evade hazardous weather, what strategies do we advocate?

4.1 **First strategy:** Increase the skill (accuracy, precision and reliability) of the weather forecast

The first strategy is simply to increase the skill of hazardous weather forecasts. If such a strategy were successful, traffic flow managers could work with increased confidence in their decisions to mitigate congestion. Unfortunately, forecast skill beyond a few hours is low, and the best technical evidence from the science community (NRC, 2002) is that improvement in forecast skill will be incremental; that is, we can anticipate no technical breakthroughs in the immediate future. However, this approach is important and must be sustained.

4.2 **Second Strategy**: Mitigate the impacts of weather forecasts on traffic management in the NAS.

In order to make operational changes, however, weather information must not only be "better", but it must also be used more effectively. The existing, uncertain operational weather forecasts can be used for air traffic decisions that will *mitigate*, but not eliminate adverse impacts on the NAS. This requires an *understanding* of the strengths and weaknesses of new weather products, and *training* on the use of weather information for traffic management. Included in this strategy is an integration of a spectrum of weather products to avoid overlap and confusion. Improving the training will require the development of "best practices" that are a result of operational experience, and a systematic, two-way *feedback* from the experience of mistakes and triumphs between Users and the Providers of weather forecasts--both in the National Weather Service and from commercial weather centers

4.3 **Third Strategy**: Manage the reaction to traffic flow decisions in the context of actual weather

Finally, in order to achieve full operational change, *reactions* to redirecting flights into a conflicting stream of traffic must be anticipated….before the decision is made. Note that although hazardous weather restricts airspace, the decisions of Traffic Management Specialists and Traffic Controllers can also concentrate traffic flows in other regions of the airspace that subsequently requires a secondary cascade of traffic initiatives. This circumstance is exacerbated by the uncertainty in the location of the hazardous weather and the sheer number of aircraft that need redirection. In this environment, "better" weather information is insufficient by itself; it must be used in conjunction with traffic management tools to *manage* the consequences of traffic decisions that were first initiated in reaction to hazardous weather threats. This can best be done through the development of Decision Support Systems (DSSs) and tools that automate weather forecast information into the decision process.

4.4 Operational Change

Figure 3 identifies the priority areas where these strategies can be applied to influence operational change. Although the expectations from the first strategy are limited, a key element is thunderstorm forecasting for improving NAS predictability by extending the forecast lead-time and improving the accuracy. The forecasting targets for thunderstorms are initiation, growth, decay, coverage, tops, intensity, and movement. However, the *application* of (uncertain) these forecasts to traffic flow management holds the most promise for achieving operational change.

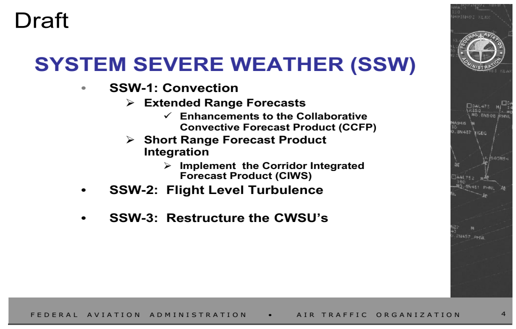

Figure 3 – The SSW Quadrant has 3 subprojects: Convection, Flight Level Turbulence, and CWSU Restructuring. There are 2 subprojects to address convection within SSW-1. (Kies, 2004).

Secondly, the *Mission Need Statement for Aviation Weathe*r (FAA, 2002) identifies other priority areas in addition to thunderstorms: Flight Level Turbulence presents similar hazards and restrictions to airspace although they are sharply defined in the vertical dimension. The anticipated success in achieving operational change is highly dependent on engineering developments coming from scientific investigations and research. For turbulence, the focus is the forecasting of intensity and coverage, especially in the vertical dimension, and evolution in time.

Third, the Restructuring of the CWSUs holds the promise of substantially improving the application of weather forecasts to the forecasts of air traffic capacity in the NAS—both for the terminal and TRACON, and subsequently, for sectors and routes. Nowhere within the NAS are weather forecasts more closely linked to traffic management than at the CWSU, except in automated systems; eg, CIWS.

All of these attempts to influence the operational metrics of NAS performance need to be integrated into a coherent operations concept. Improved forecasts of hazardous weather cannot be expected, alone, to produce the desired results. How these improved products are disseminated, displayed, interpreted and ultimately applied is most critical for success. The development of applications of weather forecasts is the path to achieve success.

Feedback to the producers of forecasts depends on a resident database of coincident weather and traffic data. Moreover, real time feedback to the system stakeholders, as well as the forecasters, will stimulate traffic modeling, risk management and lessons learned. This is the mechanism for continually improving the management of the system.

Operational change can be initiated through a common understanding and awareness of the weather forecast, followed by practical guidelines from experience. On this foundation it is possible to design procedures for strategic planning, decision-making and tactical adjustment.

Looking to the future, TFM systems will be based on identification of potential constraints by the FAA, leading to common situational awareness among the stakeholders and subsequent flow alternatives, The objective is user-preferred trajectories that are consistent with TFM strategies which maximize the available capacity in a safe and secure manner. Therefore integration of weather information into the strategic planning process is the key to enabling dynamic adjustments of traffic management initiatives for increased customer flexibility within a *global* air traffic flow management system.

4.5 INTEGRATION

Finally, to achieve operational change, the ultimate goal and most difficult objective is to integrate weather information and forecasts into Decision Support Systems (DSSs) -- automated procedures that will, 1) integrate weather with traffic information, and 2) integrate the application of weather and traffic information across different time scales.

The first part of the integration is familiar to meteorologists and traffic managers—using observations and forecasts to make experienced but subjective decisions to redirect traffic. Moving toward the rim of the sector in Figure 4, we encounter more difficult tasks that require increasing collaboration of different specialists: Meteorologists, Traffic Managers, and Operational Researchers. The goal of DSSs can be achieved by identifying an *operations concept* for

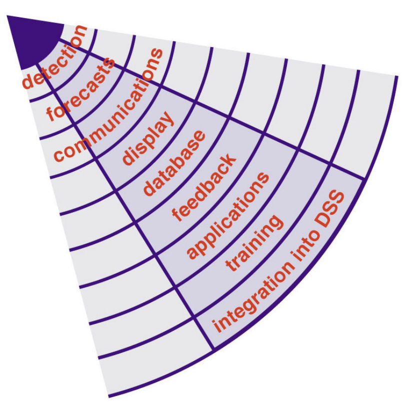

Figure 3 – The radial development from detection, through forecasting, to applications and ultimately, to the integration of weather and traffic forecasts into Decision Support Systems (DSSs).

using weather forecasts, and incrementally improving them, or by encouraging operations researchers and meteorologists to develop a new vision and different procedures.

First, DSS tools will advise traffic managers on decisions to mitigate the impacts of hazardous weather. Secondly, DSSs are used diagnostically to evaluate the consequences of possible traffic management options.

Some examples of this integration are beginning to appear. The concept of FEA (Flow Evaluation Areas) can be easily adapted to forecasts of convective weather that also occupy areas of airspace. The RAPT (Route Availability Planning Tool) explicitly integrates weather forecasts into advice for scheduling aircraft attempting to depart from terminals.

However, we recognize that DSS tools alone will not create substantial operational change that is our goal. Since our operational objective is to maximize through-put within the available airspace, and the key is how well we can interpret the weather information and forecasts and integrate that information into our decision making processes. We are challenged here by the current lack of integrated weather display standards. Various products use different colorations, scaling, latencies and refresh rates. Achieving a common situation awareness is needed as a basis to develop traffic management strategies within NAS constraints and, subsequently, implementing a plan effectively to maximizes throughput.

Similar to a football coach preparing for a game, we need to develop a plan against our weather adversary based on the best forecasting skills available. Subsequently, as game time approaches, and based on new information, a practical coach would reevaluate the strategic plan and continually make tactical adjustments as necessary.

Successful integration of real-time weather and DSS tools will mitigate the impact of hazardous weather on the system only if it also includes the integration of TFM processes, procedures, planning, and execution as well.

The double integration of weather forecasts, traffic and applications that has been described is still at an early stage, although this is the ultimate goal in the SSW Quadrant. It will drive investments in both weather research and air traffic operations research for the next decade. This objective is also shared with the second project (ER-2) of En Route Traffic Management Quadrant.

5. WHERE DO WE GO FROM HERE?

During the organizational transition in the FAA Air Traffic Organization (ATO), several planning documents were developed that are compatible with the SSW Quadrant. Regardless of the direction that is taken, the concepts and projects developed under the OEP SSW Quadrant will be sustained in some form.

The proposals of this paper will be incorporated into V7.0 of the OEP by the end of the year. The projects described by convection, flight level turbulence and CWSU restructuring will be carried by their advocates and receive organizational support only because they are able to show a potential for operational change.

6. CONCLUSIONS

The primary FAA mission that is refocused by the Air Traffic Organization (ATO) is a renewed the emphasis on air traffic operations and efficient use of air space, while maintaining the highest standards for safety of flight. In this regard hazardous weather can take up a considerable piece of available resources in the NAS and works to limit the options available to traffic managers.

Weather forecasts (accurate, precise and reliable) are essential for efficient air traffic management. Moreover, the derived benefits become available when traffic management is able to mitigate weather impacts by making conditional decisions with uncertain forecasts and testing alternative strategies beforehand before managing the consequences in the NAS. Air traffic managers can do this complex task most effectively when they work with the aid of automated Decision Support Systems.

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