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COLLABORATIVE DECISION MAKING (CDM) WEATHER EVALUATION TEAM (WET) PAST AND PLANNED WEATHER INTEGRATION EFFORTS WITH CONVECTIVE FORECASTS

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1. INTRODUCTION

The Weather Evaluation Team (WET), a Collaborative Decision Making (CDM) Subteam, is responsible for addressing meteorological issues, including convection, with the other CDM Subteams. The CDM Stakeholders Group (CSG) recently directed its Subteams to focus on topics related to the Next Generation Air Traffic System (NextGen). In 2010, the WET investigated a concept involving human forecasters, probabilistic weather and the integration of weather into air traffic management (ATM) decision making. Considered both 'revolutionary' and 'traditional', this process has been dubbed *operational bridging*.

The notion of operational bridging resulted from a number of converging requirements and events:

- The need to evolve the Collaborative Convective Forecast Product (CCFP), which, until recently, could have been considered a Single Authoritative Source (SAS) for ATM decision making.
- The recent introduction of additional automated convective forecast products to ATM decision makers (e.g. the Corridor Integrated Weather System [CIWS], the Consolidated Storm Prediction for Aviation [CoSPA] and the Localized Aviation MOS Program [LAMP] Collaborative Convective Forecast Program [CCFP] Hybrid [LCH]).
- The direction of CSG to its Subteams to focus on NextGen-related topics.
- Recent interaction between the WET and the National Weather Service (NWS) Space Meteorology Group (SMG) at the Johnson Space Center (JSC) in Houston, TX.

The paper opens with background information on CDM and early convective weather forecast products, including CCFP, followed by a discussion of the variety of additional convective forecast products being used by ATM decision makers today. The paper next describes operational bridging at a fairly high level, links the development of operational bridging with the evolution of CCFP and concludes by providing future steps being

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considered by the WET in an attempt to better define and test the concept.

1.1 *Background – Early CDM*

Over the last two decades, proponents of the concept of collaborative decision making by aircraft operator and Federal Aviation Administration (FAA) air traffic representatives have worked diligently to find ways to institutionalize and strengthen this process, in part by sharing a wide variety of data types and information. Access to Aircraft Situation Display to Industry (ASDI) by operators was an early, key data sharing success in the early 1990's. Shortly thereafter, the CDM organization was founded.

For the first few years of its existence, CDM operated primarily in an informal, grass roots fashion. In the last decade, despite the fact that all industry participation is performed on a volunteer basis, CDM has become a stronger and more formalized organization.

Collaborative efforts related to convective weather forecasting and associated decision making have undergone a similar evolution, becoming less informal and more organizationally structured within CDM over time. Throughout this transition period, however, concepts such as the role of the meteorologist in human-in-the-loop forecast processes and the best use of probabilistic weather forecasts in strategic ATM decision making have been a consistent focus.

1.2 *Background – Early Convective Weather Forecast Products*

In response to commercial air traffic accidents in the 1980s which took place in the arrival or departure phases of flight with thunderstorms near the airport, the FAA Aviation Weather Research Program (AWRP) funded field prototypes operated by MIT Lincoln Laboratory to help determine the cause of the accidents. It was concluded that the thunderstorms had produced microbursts, a characteristic of which was rapidly changing wind speeds and directions across a small area. Depending on the magnitude of the velocity change, an aircraft encountering these variable winds could experience a significant loss of lift (Wolfson et al., 1984). In order to locate regions of microbursts, a new radar system, known as the Terminal Doppler Weather Radar (TDWR), was created by MIT Lincoln Laboratory.

As research continued and technology advanced in the 1990s, additional aviation weather hazards were integrated with the TDWR information into an easy-to-interpret convective weather display for air traffic managers known as the Integrated Terminal Weather System (ITWS) (Evans et al., 1994). ITWS was the first system to include a so-called *radar-forward* forecast display of the convection and related hazards. More detailed information concerning the evolution of this family of products can be found in Appendix A. Two more recently introduced systems that are direct descendants of ITWS and leverage the radar forward forecast display methodology are identified in Section 1.4.

During this same mid 1990's timeframe, ATM decision makers and meteorologists recognized the need for a single, consistent, high-quality convective weather forecast product to identify projected thunderstorm impacts in the continental United States (CONUS). By 1997, two explicit goals had been identified for such a product:

- It should be collaboratively produced.
- Information from it should be collaboratively applied to system-wide ATM decisions for the National Airspace System (NAS).

From these needs and specific goals came the Collaborative Convective Forecast Product (CCFP). It was developed, prototyped and tested in 1998 and began being used operationally on a large scale by 2000. The origins of the CCFP from the perspective of the NWS Aviation Weather Center (AWC) are described in Rodenhuis, Mosher and Fahey (1999), while Fahey et al. (1999) recounts the CCFP inception from the vantage point of the aircraft operator.

Since 1999, the CCFP has been produced by AWC forecasters, who also manage the collaboration between themselves, Center Weather Service Unit (CWSU) meteorologists at affected FAA Air Route Traffic Control Centers (ARTCCs) and forecasters representing individual aircraft operators.

Until recently, the CCFP had been used as the sole convective weather forecast source for the daily strategic planning process which takes place every two hours, is facilitated by personnel at the FAA Air Traffic Control System Command Center (ATCSCC) and includes aircraft operator ATM decision makers. As such, the CCFP can be considered to have been an early example of a fundamental NextGen concept, namely the SAS weather product.

1.3 *Background – CDM weather-related efforts, AWRP-sponsored research and the evolution of CCFP from 2000 through 2007*

CCFP became operational in 2000. In the intervening time, the product and process have continued to evolve. Two years later, in 2002, CDM formally created a weather-centric team. That team, too, evolved considerably in the ensuing years. However, focusing on convective forecasting and the use of those forecasts by ATM decision makers would remain the primary objective of that group and its successors.

During its first operational year, CCFP was produced every four hours for 16 hours per day. In 2001, CCFP production time was expanded to 24 hours per day. A significant change took place in 2002 when the issuance of CCFP was increased from every four hours (six times per day) to every two hours (12 times per day) to coincide with the Strategic Planning Team (SPT) telephone conferences (TELCONs).

That same year, CDM sponsored the establishment of the CCFP Project Team. In 2003, the CCFP Project Team was formally reconstituted as the Weather Applications Work Group (WAWG) of CDM and the CCFP was expanded to cover eastern Canada. Plans for more intuitive graphics were formulated in 2004 and implemented in 2005, with two colors representing forecast confidence and three separate fills representing area coverage. From 2000 through 2004, a CCFP User Needs document was produced. More details on the evolution of CCFP are provided in Fahey and Rodenhuis (2004).

As mentioned previously, FAA AWRP-sponsored research had been primarily focused on convective products with shorter forecast time frames. However, that scope began expanding early in the 2000s. Utilizing the best features and lessons learned from the TDWR/ITWS development efforts, networking previously standalone radar systems and leveraging new technologies and atmospheric theories, the Corridor Integrated Weather System (CIWS) was developed in 2001 in response to growing enroute delays due to convection. CIWS provides ATM decision makers with rapidly updating automated precipitation and echo top forecasts from zero to two hours. More detailed information on CIWS can be found in Appendix B.

Beginning in late 2005, weather-related CDM activities took an approximate one year hiatus. In 2006, activities were reinitiated with the formation of the WET.

It should be noted that, from its start in 2002 through today, and regardless of its name, the CDM Subteam focused on weather and how it relates to the ATM decision making process has never consisted exclusively of meteorologists. It has always been staffed by a combination of representatives from industry and government who work or have expertise in one or both of two areas: aviation weather forecasting and/or ATM decision making. In the context of this paper, the latter term applies to individuals from both industry and government who make decisions on how aircraft will operate in the NAS. Aircraft dispatchers, air traffic control (ATC) coordinators and general aviation (GA) schedulers are industry's ATM decision makers, while managers and planners at the ATCSCC and traffic management coordinators at field facilities perform this function for the FAA.

1.4 *Background – CDM WET and AWRP-sponsored efforts from 2008 through early 2010*

In 2008, the CSG tasked the WET with evaluating and recommending a convective forecast product that would extend beyond the CCFP six-hour forecast period and add confidence to the CCFP output.

WET efforts in these areas led to the introduction in 2009 of a new convective forecast product called the Localized Aviation Model Output Statistics (MOS) Program (LAMP)/CCFP Hybrid (LCH). As the name implies, this product combines CCFP polygons and LAMP convective probabilities on one display. LCH is described in further detail in Appendix C.

This same CSG tasking influenced the development in 2010 of two additional convective forecast products intended to support anticipated long range collaborative planning activities that will extend the existing planning process out to 24 hours or more. The two new products were the Aviation Impact Guidance for Convective Weather (AIGCW) and the Extended Convective Forecast Product (ECFP). Both of these new forecast tools are described at length in Appendices D and E.

The latest member of the AWRP-sponsored TDWR/ITWS family of products, the Consolidated Storm Prediction for Aviation (CoSPA), was made available as an operational demonstration from June to October 2010. CoSPA extends the automated precipitation and echo top forecast from zero to eight hours. It is described in more detail in Appendix F.

The WET, recognizing the importance of these rapidly updated, automatically produced products, collaborated with the CoSPA program office and the two organizations agreed to participate in a joint 2010 evaluation effort of both the LCH and CoSPA.

1.5 *Background – CDM WET efforts from mid-2010 to the present*

Through the introduction of LCH in 2009 and its continuation in 2010, the WET was convinced that it had technically satisfied the CSG tasking to extend the CCFP forecast beyond six hours and add confidence to the CCFP forecast. However, it was apparent to the WET that there were still related issues that needed resolution:

A proliferation of new convective weather products intended for use in ATM decision making, both WET-initiated (LCH, AIGCW, ECFP) and those such as CIWS and CoSPA, made it increasingly difficult to expect that all ATM decision makers were relying on the CCFP as the sole source of convective forecast information. This meant that the CCFP was no longer being treated as a SAS forecast. The WET believed that efforts were needed to concentrate on the SAS concept for convective forecasts, and this could be accomplished in part by employing a meteorologist-over-the-loop process.

As part of its focus on NextGen concepts, the WET noted that, although the inclusion of LCH had introduced more detailed probabilistic information to ATM decision makers, work needed to be performed to define the optimal use of probabilistic weather forecast information in strategic traffic flow management (TFM) planning.

Case day analyses conducted by the WET in early June, 2010 to better understand the relationship between convective weather forecasts and the ATM decision making process helped solidify these ideas. Several examples of situations were noted in which forecasters from the NWS Storm Prediction Center (SPC) had identified actual convection that was evolving in ways that had not been originally forecast, and had communicated this information via their Mesoscale Convection Discussion (MD) product. Because the MD is not specifically focused on the impacts of convection to aviation, however, and was not readily available to or fully understood by ATM decision makers, optimal adjustments to air traffic initiatives in response to the changing convection forecasts and actual conditions were not executed.

In late June, 2010, the WET visited the National Air and Space Administration (NASA) JSC facilities in Houston, TX and examined the processes used by NWS SMG forecasters and their operational decision maker customers (flight directors) when dealing with forecasts of key weather parameters during space shuttle launch and recovery operations. It was clear that, in their role as technical advisors to the space program's operational decision makers, the SMG forecasters were enabling the flight directors to make binary "Go" or "No-Go" decisions by converting weather forecasts from probabilistic to near deterministic. The WET believes that a similar requirement exists in today's NAS, and that this role will become especially critical during the transition to NextGen.

The processes that were observed during this visit proved to be very important, as they provided the WET with the seminal ideas needed to transform a number of loosely connected ideas into the single, overarching concept called *operational bridging*.

2. WET PROPOSAL – OPERATIONAL BRIDGING

It is common to find at least two terms used by writers to temporally and/or organizationally classify decision making and related activities: strategic and tactical. Within an organization, strategic actions and decisions typically are the responsibility of higher level personnel and take place relatively far ahead of when their impact is expected. Tactical activities and decisions, on the other hand, are carried out by a wide range of people and their impact is normally felt shortly, if not immediately, after the action is taken or decision is made.

Depending on circumstances, as time approaches the event in question, the boundaries between the above two categories can be quite indistinct, and a great deal of overlap often exists between them. In the overlap area, the skills, processes and procedures optimized for one or the other categories of decision do not always work well. A third, intermediate decision making category is often created to help solve this problem[1].

With respect to the transition from strategic TFM to tactical ATC decision making in the face of weather uncertainty, it is similarly appropriate to create a term for the overlap area between the two domains. Because short range (0-20 minutes) ATM decisions have always been labeled *tactical* by its practitioners, the WET proposes to retain that convention, call the overlap area *operational* and label the processes which occur in this area and help transition weather forecasts from probabilistic to near-deterministic as *operational bridging*.

[1] It is common for business writers (e.g., Harris, 1998, Muckstadt et al., 2001) to call this intermediate, overlap decision making category "tactical" and the shorter range, moment-by-moment decision making category "operational", while most military writers (e.g., Macedonia, 2002, Guillot, 2005) name short range decision making "tactical", and the decision making that takes place in the overlap area between strategic and tactical "operational".

2.1 ***General Concept***

Operational bridging is fundamentally concerned with identifying the transition of aviation weather constraint forecasts from the low/medium confidence (probabilistic) category to the high confidence (near-deterministic) category and doing so early enough to enable the associated timely refinement of TFM plans. This addresses one perceived shortfall of the current system, namely its inability to react quickly and decisively to changing weather forecasts and/or terminate existing traffic management initiatives (TMIs) when weather conditions improve. Figure 1 is a diagram which depicts several of these aspects of operational bridging in the context of convective forecasts.

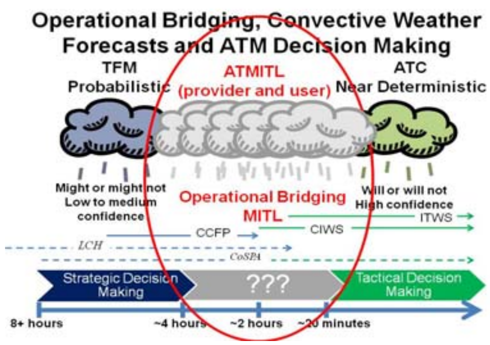

Figure 1. Graphical depiction of operational bridging for convection.

The aviation meteorologist accomplishes operational bridging by merging a solid understanding of National Airspace System (NAS) components and processes and full awareness of the atmospheric conditions that are important to ATM decision makers with advanced weather forecasting techniques and communications skills. This not only allows the focus of the operational bridging meteorologist to be on what is meteorologically crucial to aviation, but it also ensures that the decision makers receive clear guidance in a timely manner, allowing them to react quickly and decisively to changing weather forecasts and employ or terminate TMIs in a highly effective manner. As such, the WET believes that operational bridging is the area in which the aviation meteorologist can provide the greatest benefit and input to strategic TFM decision making.

Operational bridging is not normally concerned with or does not directly impact tactical ATC decisions involving individual flights. Its focus is on strategic TFM decisions from a system perspective.

The concept of operational bridging is not revolutionary, in the sense that it has never been attempted before. In fact, although it may not be similarly labeled, it is clear that successful industry and government aviation meteorology departments routinely conduct operational bridging activities in support of their ATM decision makers each and every day. Institutionalizing the process, and expanding it across all relevant areas of the CDM community, both industry and government, is not only revolutionary but challenging.

Among the new concepts associated with operational bridging are the utilization of common collaborative tools and processes and the creation of standardized, tailored aviation weather forecast products across the range of government and industry aviation meteorology groups. Additional information concerning this topic can be found in section 3.10.

A point of emphasis for the meteorologist performing operational bridging is the need to fully understand the potential impact of the forecast weather phenomenon on TFM decision making, and then consider and merge both numerical weather prediction forecasts and real-time atmospheric information. This latter function is accomplished by enabling and expecting the operational bridging forecaster to (1) maintain continuous awareness of key observed meteorological conditions within the area of forecast responsibility ("metwatch"), (2) compare the actual and predicted state of the atmosphere in order to determine the accuracy of and confidence in the existing numerical weather prediction forecast and (3) use that information to validate or adjust existing aviation weather forecasts in a timely manner. These are considered to be key components of operational bridging as the forecast weather event (or non-event) draws closer.

In addition to being a competent forecaster, becoming intimately familiar with the operation of the NAS and practicing superior communications skills, the operational bridging forecaster must also be comfortable interfacing on an ongoing basis with the operations control and traffic management personnel whom they support. Additionally, they must not stray from advising the decision maker to making the decision for the decision maker. All of these challenges are successfully met today by many airline industry meteorologists, CWSU meteorologists, NWS Incident Meteorologists (IMETs) and NWS SMG meteorologists.

Operational bridging is believed to be a natural and necessary component of the current NAS strategic planning process, along with anticipated long range collaborative planning activities. It takes place in the time period most suited for collaboration between operator strategic decision makers (aircraft dispatchers, ATC coordinators) and FAA strategic decision makers (traffic management coordinators [TMCs], planners). Because of its linkage to both current and possible future planning processes, this effort will need to be tightly coordinated with other CDM Subteams and especially the CDM Future Concepts Team (FCT) and Flow Evaluation Team (FET).

2.2 *Motivation – Linkage between CDM and NextGen Goals*

The interest of the WET in the concept of operational bridging was amplified by the recent convergence of many loosely related CDM and NextGen activities and requirements.

CDM efforts, by definition, are focused on achieving results in the relative near term. One of the consequences of the limited time scope of CDM projects has been that, until recently, the work of the CDM Subteams, including the WET, rarely if ever addressed NextGen goals when developing new products and processes.

Given that near term NextGen efforts are now underway (e.g., Automatic Dependent Surveillance – Broadcast [ADS-B], Time Based Flow Metering [TBFM]), and that the NextGen mid-term is generally defined as commencing in few years, it is no surprise that the goals and objectives of the CDM community and its Subteams and NextGen-related projects are now beginning to intersect.

2.3 *WET Projects – Traditional Core Focus*

Since its inception in the mid-2000s, many of the activities of the WET have been focused in one of two areas:

- The role of the meteorologist in human-in-the-loop (HITL) and/or human-over-the-loop (HOTL) processes that involve weather.
- The use of probabilistic weather forecast information in strategic TFM planning.

An example of a WET activity on the first of these subjects is its continuing involvement in the role of the meteorologist in the CCFP process. The work completed by the WET from 2008-2010 to identify, analyze and, in some cases, develop probabilistic convective weather forecast tools is a recent example of the second of the two traditional core focus areas of WET work. Interestingly, the WET's involvement in the second area has led it back to the first topic, as it examines the role of the meteorologist in converting probabilistic weather forecasts to near deterministic ones through the operational bridging process.

These two focus areas are also key research and development topics in the ongoing, NextGen-related efforts aimed at achieving ATM-Weather Integration. Consequently, at the same time that the WET is continuing to explore new ideas and analyze problems associated with its two core focus areas, it is performing work in support of NextGen. It can likewise be reasoned that the development of the operational bridging concept is supportive of furthering NextGen-related ATM-Weather Integration efforts.

2.4 *CDM Projects – NextGen Focus*

Appendix B of the CDM Strategy and Guidelines states that CDM should develop a two- to five-year strategy that is aligned with the FAA's Flight Plan and Operational Evolution Partnership (OEP). Given that NextGen short term projects are already underway, and that preparatory work is being performed and funding decisions are being made for Next Gen mid-term projects, it was not unexpected that the CSG specifically directed its Subteams in fiscal year 2010 (FY10) to ensure that their efforts support upcoming NextGen requirements and processes. The WET, in an effort to address this directive, has given consideration and focus to two additional weather-related NextGen concepts:

- The use of weather information from the NextGen 4-Dimensional Weather Data Cube (4-D Wx Cube), including that with SAS designation.
- The integration of weather into the ATM decision making process.

In support of the NextGen focus of CDM, the WET operational bridging proposal in one form or another addresses each of the four themes listed above.

3. CONCEPTUAL BUILDING BLOCKS

When the initial notion of operational bridging began to gain clarity, it became clear to the WET that further investigation of the topic was required. Anticipating that light would be shed on some of the key aspects and core building blocks of the process, the WET examined the work being performed by successful aviation meteorology offices and departments. Internal discussions within the WET revealed several common misconceptions and semantic discrepancies that needed resolution. The following sections highlight several of the discoveries made by the WET in the process of gaining understanding of operational bridging.

3.1 *Low/Medium Confidence (Probabilistic) vs. High Confidence (Near Deterministic) Weather Forecasts*

During initial conversations concerning operational bridging for convection, the term *deterministic* was used to characterize the type of convective weather forecasts which operations control and traffic management personnel needed to make binary (“yes” or “no”) ATM decisions in the face of convective weather. Similarly, the term *probabilistic* was used to describe the type of thunderstorm forecast which was difficult, if not impossible, for those decision makers to use. However, problems associated with these terms soon became apparent.

3.2 *Nature of Forecasts*

All forecasts, even those that predict a 0% or 100% chance of occurrence of a weather phenomenon, are fundamentally probabilistic. This is due in part to the inherent uncertainties of forecast systems in use today and for the foreseeable future, along with the relatively low density of atmospheric observation systems worldwide. Until the effect of the butterfly in Brazil on the tornado in Texas (Lorenz, 1972) is perfectly known, we are stuck with imperfect prognostications called forecasts, which are by definition probabilistic.

3.3 *Deterministic Displays*

Radar systems are used to observe the actual weather. They output deterministic information. Other than when impacted by anomalous propagation, each pixel of the radar display that is illuminated corresponds to precipitation contained in the associated column of air. The pixel color is associated with the reflectivity of the radar return, which itself can be used as a proxy for the amount of liquid in the column of air.

The output of some convective weather forecasting systems such as CIWS is also described as being deterministic. Instead of calculating and assigning a probability of precipitation for a particular location some hours in the future, these systems predict the actual location of precipitation at the time in question and then indicate its presence by illuminating the associated display pixel. For those locations expected to have precipitation, the color of the illuminated pixel corresponds to the amount of vertically integrated liquid (VIL) expected in the column of air above the location. In essence, these systems output a radar-like deterministic-looking forecast up to eight hours in advance of the event. Because ATM decision makers continually use and are very familiar with radar displays, they have found these forecast displays to be very intuitive and easy to use. However, users of these products also must understand that these deterministic-looking forecasts are fundamentally probabilistic.

At this time, probabilities are not displayed on these systems. However, accuracy scores and/or verification contours are available to be displayed on the individual forecasts to help the user understand how the system has been performing for forecast interval in question. In essence, the accuracy scores and/or verification contours act as probability proxies in these systems.

3.4 *Interpreting Forecasts Deterministically*

At key process-dependent decision times prior to the occurrence of a weather event, or at some critical threshold probability value, whichever occurs first, weather forecasts transition from being viewed, thought of and reacted to probabilistically to being viewed, thought of and reacted to deterministically. A forecast that is being interpreted deterministically provides a binary, yes/no answer, e.g., a thunderstorm <u>will not</u> be located at point XYZ in 20 minutes, or a wind shift <u>will</u> take place at airport ABC at time TTTT. Tactical decision making in the face of forecast weather constraints or changing weather conditions relies on being able to interpret forecasts deterministically. The same is not true for strategic decision making, which can use either pure forecast probabilities or forecasts that have been interpreted deterministically.

3.5 *Relationship between Confidence, Probabilities and Deterministic Interpretation*

Aviation meteorologists who support ATM decision makers understand that they will ultimately be required to interpret most forecasts deterministically and deliver a binary “Yes” or “No” answer to their customers. For some forecasts, especially the occurrence and onset of convective, freezing or frozen precipitation, it is not always possible to deliver a binary answer at the time the question is asked. Common strategies used by the forecaster in this situation are bet hedging and forecast qualifiers.

When the confidence of the forecaster is sufficient to allow it to be stated that a certain weather event will or will not occur, then that forecast can be thought of as having been interpreted deterministically, and considered to have transitioned from being probabilistic to near deterministic. A forecast for which the same meteorologist's confidence is either low or medium will likely not result in a deterministic interpretation, and will continue to be viewed as probabilistic.

The transition of forecasts from probabilistic to near deterministic, which is related to the amount of confidence that the forecaster has in the prognostication, is a key component of operational bridging.

3.6 *Strategic vs. Tactical Decision Making*

The words *strategic* and *tactical* have different meanings depending on the context in which they are used. For the purpose of this paper, strategic decision making refers to those decisions made in support of the ATM activities collectively called TFM, while tactical decision making is done in support of the ATM activities called ATC.

Ultimately, all TFM actions are taken to support downstream or future ATC activities. Aircraft dispatchers and ATC coordinators are an airline's strategic decision makers. Supervisory traffic management coordinators (STMCs) and TFM planners are the strategic decision makers for the FAA.

3.7 *ATM Decision Making Timeframes*

Although rigid timeframes are not explicitly used in this paper, tactical or ATC decision making is generally thought to take place no more than 20 minutes from the expected event, while strategic or TFM decision making can take place anywhere from 20 minutes to days ahead of time.

3.8 *Decision Making vs. Execution*

Decision making should not be confused with execution. A controller who assigns a new course or altitude to an aircraft, and then verifies that the new trajectory is being flown, is executing one or more ATC actions. However, the execution of those actions may have been prompted by either a TFM decision or an ATC decision.

3.9 *Decision Making Types and Forecast Types*

It has been asserted that all current weather forecasts are probabilistic by definition. A weather forecast becomes near deterministic, or deterministically interpretable when, in the opinion of the decision maker, the probability of occurrence becomes low or high enough to allow a high confidence yes/no decision to be made.

Because tactical, ATC decision making is binary, a near deterministic forecast is required when the decision involves weather. Often times, the tactical decision maker is forced to make this decision without the benefit of input from an aviation meteorologist, relying instead on personal experience and intuition. Pilots are tactical decision makers of the operators, while air traffic controllers are the FAA's tactical decision makers.

Strategic decision making can use deterministically-interpreted weather forecasts if they are available in the time frame in which the strategic decision is required to be made. However, weather forecasts available hours ahead of a constraining weather event, especially one involving convective activity, are almost always highly probabilistic. This implies that optimal strategic decisions based on a forecast of convective weather should most often result in the creation of multiple, incremental solutions, to account for the uncertainty associated with the probabilistic weather forecast. It also means that the execution of the plan should be based on required lead times and the incremental solution associated with the most likely weather outcome.

3.10 Future Collaborative Planning Processes

In anticipation of the development and implementation of long range collaborative planning processes with lead times of 24 hours or more, MITRE researchers have proposed an approach that is similar to the NWS three-tiered concept for alerting their customers and partners who need considerable lead-time to prepare for hazardous weather.[2] The NWS concept uses product names such as "Outlook," "Watch," and "Warning" (or "Advisory" if warning thresholds are not met) to alert for potentially significant weather.

Based on this, MITRE developed the TFM Weather Management Matrix model (Figure 2) for future long range planning processes. It proposes the use of a three-tiered approach based on the increasing risk of impact to the NAS as a function of time.

The intent of the matrix is to apply standard definitions and levels of response required by the system users based on identified weather

[2] More information on the NWS scheme can be found at http://www.wrh.noaa.gov/slc/productguide/CH4.php

trends and events. This process can be utilized from strategic operational planning right through to tactical operations.

Use of this type of multi-tiered approach could lead to proactive, incremental decision making by all NAS stakeholders in anticipation of weather related constraints. It would enable decision makers to build upon collected knowledge and incrementally raise system

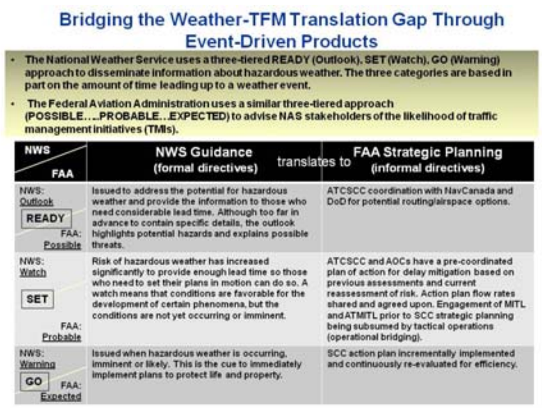

Figure 2. Possible standardized three-tier forecast products matrix that could be used in operational bridging.

awareness of significant weather impact and any subsequent mitigation plans while providing a platform for common situational awareness (Huhn et al., 2010).

4. OPERATIONAL BRIDGING AND THE EVOLUTION OF CCFP

As outlined previously, new forecast products have become available to the traffic management community. CCFP has seen some improvements and modifications over the years and remains the single official convective forecast used for ATM decision making. However, tools such as CoSPA and LCH are introducing additional forecast data into the ATM decision making process. A question that arises is how to rectify multiple forecasts of the same weather element into a common answer.

A logical solution to the challenge of converting multiple convective forecast products into a single authoritative source is to combine them in ways which leverages their strengths, minimizes their weaknesses and makes possible consistent longer range planning and decision making. To accomplish this, it is believed that evolutionary changes to the CCFP production and collaboration processes are necessary, and that operational bridging for convection will be a key component of the transition.

4.1 *Initial Implementation for Convection*

Although the operational bridging process can and should be applied to any forecast weather constraint, the WET proposes that the initial exploration and implementation of the concept be focused exclusively on convection. This is in order to be consistent with the previous CSG tasking relating to convection and to acknowledge the fact that, of all weather constraints, convection has the greatest impact on the NAS.

4.2 *Proposed CCFP Evolution*

CIWS has been shown to provide a very useful two-hour convective forecast (Robinson et al., 2006). It is believed by many in the weather and ATM communities that the automatic, rapidly refreshed two-hour CIWS forecast should be used in place of existing two hour CCFP polygons. Since CIWS automatically and continually updates its two-hour forecast, whereas CCFP two-hour forecasts are manually issued once every two-hours, the use of CIWS forecasts in the zero- to three-hour timeframe would make better forecast resolution and accuracy available to ATM decision makers as compared to what is provided by the current two-hour CCFP graphic. If CIWS were to become the source of the two hour convective forecast, CWSU, airline and AWC meteorologists would be able to modify the CCFP collaboration process and produce four-, six- and eight or more-hour (4/6/8+) convective forecasts. The combination of CIWS and CCFP would extend convective forecasts for aviation out to eight hours. This would enable ATM planning for convection to also be expanded out to eight hours, and allow forecast guidance from new tools such as LAMP, AIGCW, CoSPA and ECFP to be considered alongside and potentially integrated into the CCFP solution, facilitating even longer range TFM planning.

Another evolutionary change to CCFP currently being considered by the WET involves the automatic production of first guess CCFP polygons based upon available probabilistic and ensemble model guidance. Forecasters at the AWC have the capability today to generate the underlying CCFP "ingredients" from a digitally gridded database. Using this method would allow digital, gridded probability of convection and echo top information to be provided along with the polygons, and would facilitate the automated integration of CCFP forecasts into weather translation algorithms and decision support tools. By combining the gridded components, CCFP polygons could be produced much more efficiently, and would be consistent with both the underlying gridded data and other convective products based off the same gridded forecast data. Related human input and collaboration should diminish over time, with the ultimate goal of having the final product fully automated but with continued meteorologist-over-the-loop (MOTL) involvement.

The WET has already begun working with industry, FAA and NWS to incorporate these changes as early as the 2012 convective season. Specifically, the WET is proposing that the CCFP should be transitioned from a two-, four- and six-hour (2/4/6) convective forecast to a 4/6/8-hour convective forecast, and that the initial CCFP polygons and related thunderstorm probability and echo top information should be automatically produced from gridded AWC databases.

4.3 *Role of the Meteorologist in Operational Bridging for Convection and the Evolved CCFP*

Significant improvements in the accuracy and timeliness of computerized weather forecasts have resulted in a variety of benefits to society as a whole and aviation in particular. They have also caused subtle but real changes in the role of the meteorologist. Whereas weather forecasts used to germinate in the mind of the meteorologist, now they originate from one of several highly sophisticated forecast models. This should not be construed as suggesting that meteorologists no longer make forecasts. Today's aviation meteorologist continues to make forecasts, but normally only after being provided with a first guess from a numerical weather prediction (NWP) forecast model. More and more, in addition to performing traditional forecasting duties, the meteorologist also plays the role of arbiter between conflicting model forecast solutions, translator of weather information into operational weather constraints and, in the case of the operationally savvy aviation meteorologist, technical advisor to operational decision makers.

A basic tenet of operational bridging is that the meteorologist's role in the process be redirected from typing or drawing forecast information to identifying alternate credible solutions, changes in forecast solutions (both toward or away from a previous solution) and communicating the *impact* of the weather to traffic managers in a way that is prioritized to their decisional needs and thresholds.

There is also a need for TFM initiatives to be developed with greater advance lead time, while simultaneously being "flexible" in the transition period from tactical to strategic time frames. As NextGen era decision support tools are developed and refined, and probabilistic and ensemble weather information is integrated in TFM decisions, we must look to evolving current weather information and products.

In the current CCFP production process forecasters spend time creating, collaborating on and editing polygons and text products. Little time is available for the meteorologist(s) to focus on the impact of the constraint on the NAS, and to identifying and communicating changes in the forecast meteorological conditions based on impact thresholds. The use of operational bridging for convection combined with the incorporation of the previously described changes to the CCFP production process and the consideration of new convective forecast guidance will give the aviation meteorologist the opportunity to continuously monitor the atmosphere, detect differences between forecast and actual weather and effectively communicate those discrepancies that have will have significant impact to the NAS via a standardized convective forecast product such as an Aviation Weather Statement (AWS), which is described in the next section. It is believed that these capabilities have the potential to add significant flexibility to ATM decision making related to convective weather.

5. FUTURE ACTIVITIES – OPERATIONAL BRIDGING FOR CONVECTION

The WET is in the initial stages of planning both a table top exercise and an operational test of the concept of operational bridging for convection. As depicted in Figure 1, the WET is assuming that CIWS, CoSPA and LCH products will continue to be produced and will be used in the both table top exercise and the operational test. These three scheduled products will be used as the primary inputs while a variety of other human-produced and numerical weather prediction model-based thunderstorm forecasts will also be used, but as secondary inputs to the convective operational bridging process. It is assumed that the CCFP portion of the LCH product will be unchanged in 2011 from the 2010 CCFP. It is also anticipated that the CCFP will shift from a 2/4/6-hour forecast to a 4/6/8-hour forecast in 2012.

Operational bridging for convection will then address specific convection events that impact TMI decisions using an event driven process. During the testing and demonstration it is assumed that there will be two event-driven, unscheduled types of information generated: meteorologists continually evaluating the primary products via an ongoing chat capability and a derivative product which may be called an AWS (Figure 3). This product fills the HITL void if the CCFP transitions to a 4/6/8-hour forecast. AWS also augments operational bridging for convection by indicating to the aviation community that strategic planning for this particular region is about to be subsumed by tactical operations based on the transition of the convective forecast from low-medium confidence/probabilistic to high confidence/near deterministic.

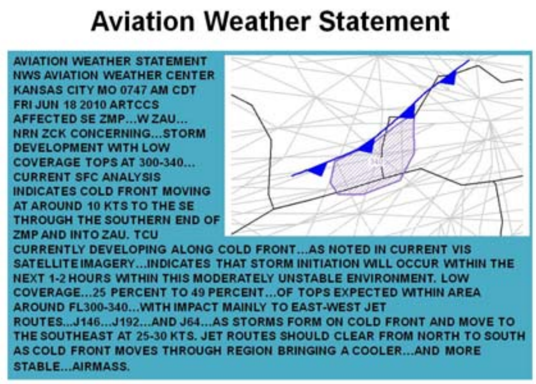

Figure 3. Notional Aviation Weather Statement with MITL inputs and a lead time of one to three hours.

It has been proposed that the testing and demonstration address three scenarios:

- Waiting for convection initiation and/or cessation.
- Convective weather active and verifying.
- Convective weather active but not verifying.

It is also assumed that AWS will be event driven, with an initial issuance based on one of the following triggers, whichever comes first:

- A high level of forecast confidence in the convective event.
- A threshold of three hours prior to the anticipated occurrence of the convective event.[3]

Since operational bridging for convection focuses on both the production of weather information via the proposed chat and AWS as well as the ATM decision making process, representatives from both groups will need to participate in the testing and demonstration.

[3] This threshold is based on TFM Requirements Work Group feedback.

5.1 *Testing & Demonstration – Pending Details*

Government and industry representatives from both the meteorology and ATM communities will participate in the testing and demonstration. Identification of the lead organizations for each of the two groups is still work in progress.

The WET has identified the need for a non-telephonic, software-based communications platform to facilitate the collaborative portion of the operational bridging process during testing and demonstration. Along with additional personnel required (e.g., human factors experts) and a source of funding, the communications software to be used has yet to be determined.

5.2 *Transition to Operational*

CDM in general and the WET in particular have a successful track record of completing testing and demonstrations in a timely manner. However, the ability of CDM to convert a tested concept into a funded operational system has traditionally been a difficult task, in part due to the volunteer status of many CDM members. A significant amount of work will be required to address this issue.

The extent of the discussions to date on the transition of a successfully tested operational bridging concept to an operational process have been that forecaster resources previously used on CCFP collaboration could be redeployed in support of convective operational bridging. And it has been recognized that before going operational, there will also be a need to identify the air traffic management resources that will collaborate in the process.

6. SUMMARY

Operational bridging may be thought of as an adjustment and enhancement to the initial CCFP process. The CCFP concept applied a collaborative approach to both the production of a convective forecast by the meteorologist and the application of the convective forecast product by ATM to support system-wide traffic management decisions. For over 10 years, CCFP production has been accomplished manually once every two hours. Collaborative strategic ATM planning continues to be similarly performed once every two hours.

Operational bridging for convection continues to involve meteorologists as information and product providers and air traffic managers as decision makers. But rather than having the meteorologists explicitly producing collaborative convective forecasts every two hours and then the ATM representatives collaboratively adjusting the plan once every two hours, the convective operational bridging process requires that the community of aviation meteorologists continually evaluate the wide variety of automated products, such as CoSPA, CIWS, LCH and other human produced convective forecasts and computer model output. The next step from the meteorological perspective is to effectively communicate both scheduled assessments of the convective forecast information along with unscheduled evaluations when appropriate for the time period of one to three hours. The expected result is a collaborative, manually produced SAS convective forecast that will act to bridge the longer term, low-medium confidence probabilistic information with short term, high confidence near deterministic forecast information and can then be used by the air traffic managers to make timely ATM decisions.

The methods for effectively communicating and then evaluating the SAS convective forecast product, as well as the process and criteria to be used by ATM decision makers to make ATM decisions such as TMI adjustments based on the new product, need to be tested during the 2011 and subsequent convective seasons.

The overall goal and measure of success of the operational bridging process, regardless of the weather constraint in question, will be an improvement in the ability of air traffic managers to make better, quicker ATM decisions resulting in shorter duration, or smaller TFM initiatives. Success in this area will lead to an incremental increase in air traffic capacity during periods of weather-related impact in the NAS.

7. ACKNOWLEDGEMENT

The CDM WET would like to acknowledge and thank Kurt Van Speybroeck, Frank Brody and the rest of the NWS Space Meteorology Group team for hosting our June, 2010 meeting and for providing us with the knowledge that was needed to crystallize the notion of operational bridging. We are grateful for their hospitality and insight.

8. DISCLAIMER

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APPENDIX A.

EVOLUTION OF FAA AVIATION WEATHER RESEARCH-SPONSORED CONVECTIVE DISPLAY SYSTEMS

During the 1980s numerous air traffic accidents were reported during thunderstorms as aircraft arrived or departed an airport. The FAA AWRP funded field prototypes operated by MIT Lincoln Laboratory to determine the cause of the accidents. It was determined that rapidly changing velocities across a small area caused a significant loss of airspeed, and thus lift for an aircraft (Wolfson, et. al. 1984). In order to locate these regions of wind shear and the more severe microbursts, a new radar known as the TDWR was created by MIT Lincoln Laboratory.

The 1990s saw continuing aviation weather research into how to predict wind shear and microbursts with automated algorithms to increase safety. The new system, known as ITWS, used TDWR data in combination with several other types of data such as surface wind data at the airport, Airfield Surveillance Radar 9 (ASR-9) precipitation data, Next Generation Radar (NEXRAD) data as well as lightning data (Evans, et. al. 1994). Information on the situation displays were automated and rapidly updated. The situation displays of the integrated data were given to air traffic towers, terminal radar approach control facilities (TRACONs), and en route facilities. Field testing was done by prototypes and numerous user group meetings. The outcome of this aviation weather research was the deployment of ITWS at 35 U.S. locations covering 47 airports (Souders et al., 2002).

Throughout the original ITWS research it was noted that some facilities needed to have more than one ITWS to cover individual airports which were in their airspace. Manually integrating all of the information of each ITWS became a challenge. Additional integration of several ITWS systems was needed in order for traffic managers to have a better understanding of what to anticipate as weather moved into a congested portion of airspace.

In 2000, air traffic suffered very high delays attributed to weather. In 2001, under the direction of the FAA AWRP, MIT Lincoln Laboratory was tasked with integrating data across a larger portion of airspace. The initial focus was on the highly congested “corridor” between Chicago and New York. Data from NEXRADs, along with satellite and lightning information, were integrated into a prototype system known as CIWS (Evans, et al., 2002). Input from user group meetings with air traffic managers and industry along with feedback from daily operations created a list of requested aviation weather products needed to improve air traffic management.

The 2000s saw advances in both aviation weather research and computing power, which led to improvements in automated precipitation and echo top forecasting. In spring 2011, CIWS is scheduled to be integrated with the new air traffic management traffic situation display, fulfilling a long standing user request. Details of CIWS are located in Appendix B.

During the development of the automated forecast products of CIWS, many users requested that the automated forecast extend beyond two hours. Taking an automated approach of forecasting beyond two hours required additional research. Statistics show that simply moving current weather forward beyond the tactical timeframe of two hours leads to a decline in accuracy (Pinto, et. al. 2010). Model data was needed to support initiation and tracking, especially in the strategic two- to eight-hour time frame. CoSPA was developed to integrate both the CIWS forecast and High Resolution Rapid Refresh (HRRR) model data using a unique blending algorithm developed by three research laboratories: MIT/Lincoln Laboratory, the NOAA Earth System Research Laboratory (ESRL), and the National Center for Atmospheric Research (NCAR). CoSPA is described in Appendix F.

APPENDIX B.

CORRIDOR INTEGRATED WEATHER SYSTEM (CIWS)

CIWS (Figure 4) was developed by MIT/Lincoln Laboratory under direction of the FAA AWRP office. Much of the air traffic delay experienced by the airlines and the traveling public occurs during summertime thunderstorm season. Efficient and safe air traffic flow management requires high resolution, accurate, rapidly updating weather information. This is especially true in highly congested airspace such as the corridor between Chicago and New York.

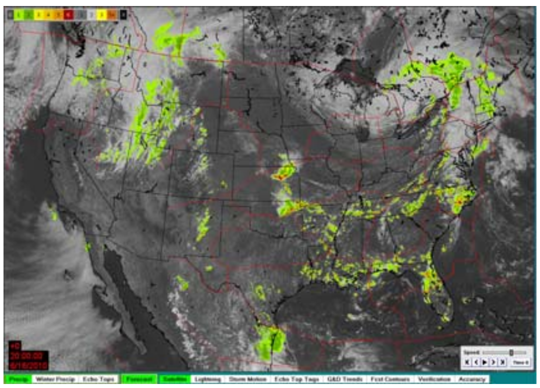

Figure 4. Example of the Corridor Integrated Weather System (CIWS) display which is a fully-automated “tactical” zero- to two-hour forecast.

In 2001, MIT/Lincoln Laboratory initially targeted the corridor between Chicago and New York. MIT/Lincoln Laboratory held several user group meetings with air traffic managers and airline representatives to prioritize the development of products and coverage. The product suite was expanded to include high resolution echo tops of precipitation. Air traffic managers found that having high resolution echo tops provided helpful guidance on if air traffic could operate safely over some of the precipitation. Shortly thereafter, expansion was done in coordination with NavCanada to cover that portion of Southern Ontario and Quebec in which were located the so-called “CAN routes.” The CAN routes are used often in the summer convective season when thunderstorms reduce capacity on the highly congested routes which feed air traffic to the major northeast U.S. airports.

Shortly after the real-time information was completed, fully-automated “tactical” zero- to two-hour forecasts were created for both precipitation and echo tops. The forecast depicts what the weather is projected to look like in advance, allowing air traffic managers to better utilize the airspace, improve productivity and safety, and significantly reduce delay.

In June of 2008, CIWS expanded to include the entire CONUS. This had been a long-standing user request. During the expansion, a major redesign of both the Situation Display (SD) and website were also accomplished. Overlays were expanded to include the same database used in the Traffic Situation Display (TSD).

Air traffic managers, airlines, and other users have access to the same high resolution, accurate, rapidly updating weather information. Common situational awareness helps reduce confusion when making air traffic decisions. MIT/Lincoln Laboratory continues to work closely with the FAA CIWS Program Office, FAA Air Traffic System Operations and the FAA Technical Center on technology transfer. CIWS will be integrated into the new Enhanced Traffic Flow Management System (ETFMS) in the spring of 2011 which will provide a common weather reference platform, a NextGen initiative.

APPENDIX C.

LOCALIZED AVIATION MODEL OUTPUT STATISTICS (MOS) PROGRAM (LAMP)-COLLABORATIVE CONVECTIVE FORECAST PRODUCT (CCFP) HYBRID (LCH) AND 2009 TEST

The CDM Stakeholders Group (CSG) chartered the WET to evaluate and recommend an eight- to 24-hour convective forecast product to be used for operations plan development and planning telcon discussion. For the 2009 convective weather season, the Weather Evaluation Team produced a prototype web-based application called the LAMP-CCFP Hybrid, or LCH (Figure 5). The intended purpose of the LCH is to supplement baseline guidance provided by the CCFP with an automated probabilistic forecast.

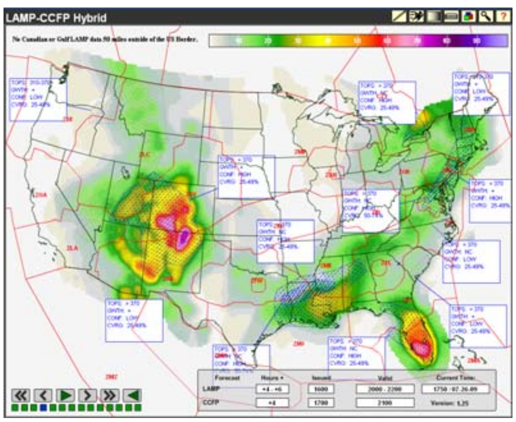

Figure 5. LAMP/CCFP Hybrid (LCH) example.

LCH combines the traditional 2/4/6-hour CCFP with the one- to 24-hour Localized Aviation MOS Program (LAMP) probabilistic convective forecast graphic, thereby providing thunderstorm forecast guidance through and beyond eight hours. It was available for use at the ATCSCC, various ATC facilities and airlines as a “test” product during the summers of both 2009 and 2010.

Prior to and during the development of the LAMP-CCFP Hybrid, the WET examined numerous scenarios for TFM utility and benefits. Additional analysis was also utilized to enhance user functionality of the prototype.

LAMP’s probabilistic output is commonly used in weather forecasts as a way to measure a degree of confidence in the forecast rather than using a single deterministic (yes/no) forecast. Use of the LAMP-CCFP Hybrid by various stakeholders has also allowed the team to evaluate how probabilistic forecasts are handled in an operational setting. Currently, traffic managers and air traffic control facilities use deterministic decision support tools. In the future, NextGen initiatives include the use of probabilistic forecasts in decision support tools.

Both quantitative and qualitative evaluations were performed at the conclusion of the 2009 convective season. The quantitative assessment suggested that the LAMP portion of LCH had modest forecast skill in certain situations. Qualitatively, the addition of LAMP was attributed with increasing user confidence in, and information about, the base CCFP forecast. Based on the criteria specified in the LCH Test Plan, the latter assessment led the WET to categorize the 2009 LCH test as being successful.

APPENDIX D.

AVIATION IMPACT GUIDANCE FOR CONVECTIVE WEATHER (AIGCW)

Analyses performed be the MITRE Corporation's (MITRE) Center for Advanced Aviation System Development (CAASD) have demonstrated that thunderstorm disruptions to the NAS can be forecast reliably well beyond six hours and even up to 72 hours before the event in some cases. However, available forecasts are not useable to FAA traffic managers because they are designed for meteorologists and do not depict traffic flow impact. As a result, the Aviation Impact Guidance for Convective Weather (AIGCW) was developed and has been operating as a functional prototype since 2009. This effort is described in greater detail by Huhn et.al. (2010). AIGCW was born from MITRE analyses conducted from the operations floor at the FAA ATCSCC along with collaboration with the NWS SPC and AWC.

Before developing a TFM plan, traffic flow managers today must develop a mental picture of the weather after viewing numerous stand-alone weather products and then integrate that weather picture with projected traffic. A goal of NextGen is to minimize the need for human interpretation of weather impacts and for automated systems to determine the optimum mitigation strategy. The AIGCW is a first step towards minimizing the need for humans to interpret aviation impact from convective weather and eventually could provide automated TFM systems with relevant data to determine a strategic response. Using reliable aviation centric convective weather data from the AIGCW permits the expansion of strategic planning timelines beyond six hours. It additionally provides a common situational awareness platform and can facilitate the synchronization of stakeholder planning initiatives to improve NAS efficiency.

The AIGCW was designed with two objectives in mind. The first objective was to provide the FAA with a reliable aviation-centric convective weather forecast on timescales greater than six hours (AIGCW forecasts extend out to three days), while the second was to illustrate for the FAA a unique capability to convert a thunderstorm forecast into operational impact to the NAS (a NextGen initiative) while making the actual weather data transparent to the end user.

AIGCW maps (Figure 6) display the juxtaposition of forecast convective weather and historical aircraft position information. The convective forecast comes from the NWS SPC Short Range Ensemble Forecast (SREF), post processed and calibrated for convective weather. The SREF is a 21-member modeling system that is run four times daily at the NWS National Centers for Environmental Prediction (NCEP) Environmental Modeling Center (EMC) in Camp Springs, Maryland.

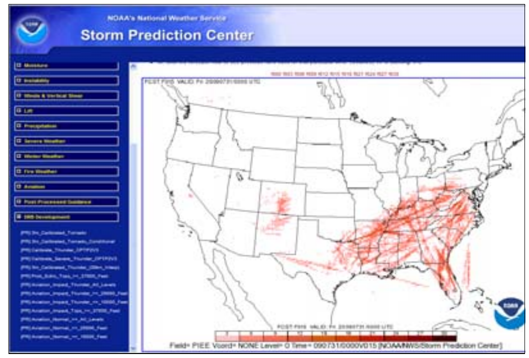

Figure 6. Example of the AIGCW display.

The composite of historical aircraft locations was developed utilizing a five-year sample set of historic air traffic data from the NAS. The data was gathered by MITRE using 1 January 2004 through 31 December 2008 as the sample set. The data consists of aircraft position messages (TZ) +/- 30 sec from the top of each hour of the day to provide the 3D profile of each airborne flight. The locations and times of these TZ messages were then plotted by hour and day of week (e.g., traffic positions on a Tuesday at 2200 UTC) onto a 20 kilometer grid of the NAS.

The AIGCW graphical maps can be tailored for the needs of flow managers by depicting potential thunderstorm impact for different altitude strata as well as impact from thunderstorm tops. Although not shown, those examples include:

- Aviation Impact at All Flight Levels (FLs).
- Aviation Impact at or above FL250 (Enroute Domain) (Figure 6).
- Aviation Impact at or below FL100 (Terminal Domain).
- Aviation Impact from Convective Echo Tops at or above FL370.

Figure 6 is an illustration of the converted weather forecast into operational disruption based on the historical (normal flow) of air traffic in the NAS at FL250 and higher. By using the Aviation Impact at or above FL250 (Enroute Domain) a traffic manager can visually see a temporal and spatial view of what particular routes or routing structure could be disrupted by convective weather from FL250 and higher at a particular hour. The AIGCW maps are currently available to all NAS stakeholders on an experimental basis and could be a key informational source for anticipated long range collaborative planning activities.

APPENDIX E.

NWS SPC EXPERIMENTAL ENHANCED THUNDERSTORM PROBABILITY, 2010 CCFP CHANGES AND EXTENDED CONVECTION FORECAST PRODUCT (ECFP)

The AWC has worked with the FAA and airline industry through the CDM WET to determine and implement enhancements and improvements to the CCFP and its associated production processes. Previously referenced papers by Rodenhuis et al. (1999) and Fahey and Rodenhuis (2004) detail these efforts.

In 2007 the AWC, in partnership with the SPC, made advancements in consistency of national convective forecasts and guidance by developing tools and guidance products. The SPC developed calibrations on the SREF guidance, details of which can be found in Bright et al. (2005) and Bright and Wandishin (2006). Several forecast elements of the SREF have been calibrated to the forecast criteria and thresholds of CCFP.

In 2008 the SPC began producing the Enhanced Thunderstorm Probability maps experimentally in support of CCFP production, TFM planning and for the aviation industry collectively.

The Enhanced Thunderstorm Probability is available to users via the web and consists of CONUS Day 1 forecasts for 1600 - 2000 UTC, 2000 - 0000 UTC, 0000 - 0400 UTC and 0400 - 1200 UTC, It is updated five times daily at 0600 UTC, 1300 UTC, 1630 UTC and 2000 UTC and 0100 UTC. These valid times were specifically chosen to coincide with the daily peak air traffic hours of late afternoon and early evening (Figure 7). Only a forecast for 0400 - 1200 UTC will be produced in conjunction with the SPC 0100 UTC Day 1 Convective Outlook.

Each of these forecasts will contain 10%, 40% and 70% contours for the probability of thunderstorms during the forecast period. Similar outlooks have been produced both internally and publicly by the SPC for three years and verification indicated these forecasts are skillful and statistically reliable. The original forecast valid time for the Enhanced Thunderstorm Probability was a time smear across 14 hours and only issued twice daily. Such a long time smear was challenging for potential use in an aviation and traffic flow management capacity. This change to the forecast valid times was a result of collaborative efforts between CAASD, FAA, SPC and AWC for probabilistic thunderstorm guidance availability during early morning hours when critical strategic TFM decisions are being made at the ATCSCC. The Enhanced Thunderstorm Probability maps are complimentary to CCFP, especially during the early morning (11z and 13z) issuances of the six-hour CCFP forecast which does not cover the late afternoon hours. The Enhanced Thunderstorm Probability forecasts provide insight to the probability for convective weather that traffic flow managers can discuss during the morning strategic planning telcons in order to help establish an efficient routing structure for the NAS.

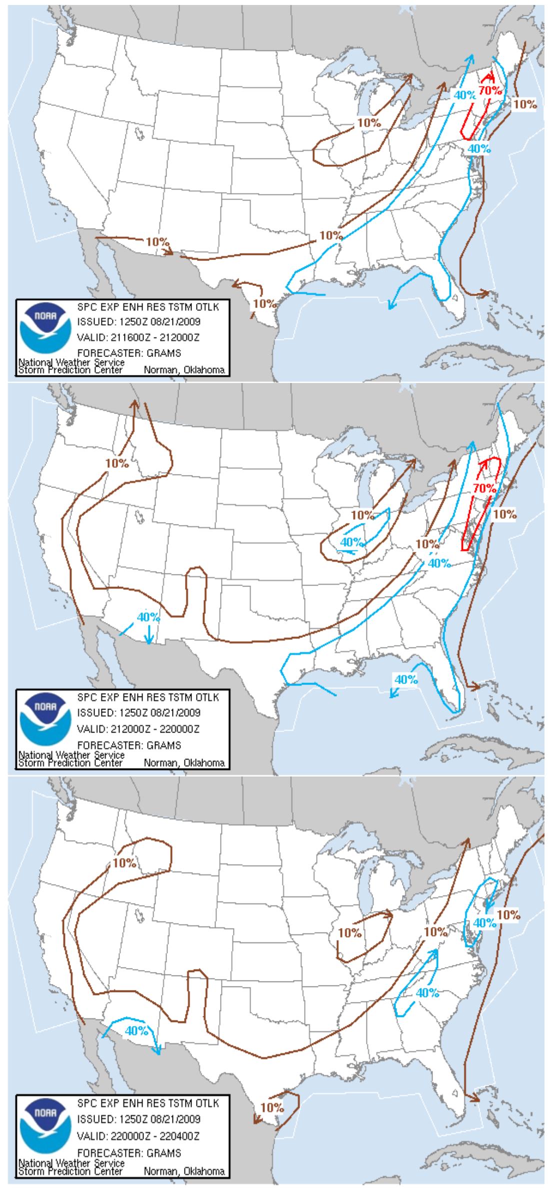

Figure 7. SPC Enhanced Thunderstorm Outlook probability maps valid 16-20z (top), 20-00z (middle), and 00-04z (bottom) are available during the early morning TFM planning telcons.

In 2010, AWC made changes to the CCFP based on recommendations from the WET.

Those changes included the elimination of text boxes and the inclusion of additional convective echo top ranges (Figure 8). Previously, CCFP forecasts of convective echo tops were divided into three ranges: FL250-FL300, FL310-FL360 and FL370 and greater. CCFP convective top forecasts are now given in four ranges: FL250-F290, FL300-FL340, FL350-FL390 and FL400 and greater.

The CCFP is collaborated between AWC, CWSU and airline industry meteorologists. The AWC produces the preliminary forecast graphics, leads the collaborative chat process, and is responsible for the final edits and transmission and communication of the CCFP.

Figure 8. Example of 2010 CCFP including echo tops information and without text boxes.

Also in 2010, the Aviation Weather Center began issuing an experimental Extended Convective Forecast Product (ECFP) (Figure 9). This automated product is issued daily at 1800 UTC and is valid for the six-hour period of 1800-0000UTC the following calendar day, making it a 30-hour forecast of convective probability. This product is based entirely on the SREF thunderstorm guidance, further contributing to a single authoritative source of underlining forecast data. The ECFP, while a probabilistic forecast of the 40%, 60% and 80% contours, uses CCFP-like shading to give traffic managers and users familiar with CCFP a consistent "look and feel".

Figure 9. Example of the NWS AWC Extended Convective Forecast Product (ECFP).

APPENDIX F.

CONSOLIDATED STORM PREDICTION FOR AVIATION (CoSPA)

CoSPA (Figure 10) provides air traffic managers, airlines, and other users a high-resolution, rapidly updating forecast of precipitation and echo tops which run in a loop from eight hours before current time to eight hours in the future. The High Resolution Rapid Refresh (HRRR) model provides the basis for CoSPA. The HRRR model is a high resolution, rapidly updating model which is a subset of the Rapid Update Cycle (RUC) model. Rapid updates are needed to forecast detailed storm structure which is a necessity in Traffic Flow Management (TFM) to maximize throughput.

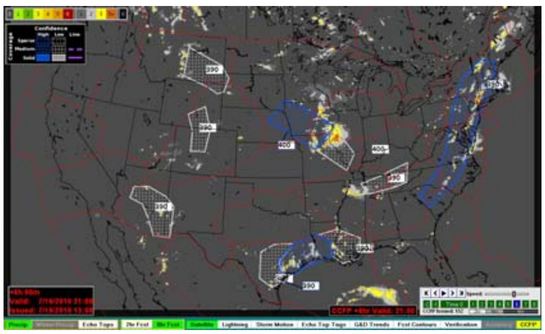

Figure 10. Example of the Consolidated Storm Prediction for Aviation (CoSPA) with the CCFP overlay.

CoSPA is funded by the FAA AWRP, and is a product of the multi-research agency effort of MIT/Lincoln Laboratory, NOAA ESRL and NCAR.

Research was started in 2007, initially across the corridor between Chicago and New York. Over the next two years, research progressed through improvements to the automated forecast and expansion of the grid size. By late 2009, CoSPA covered the entire CONUS, with additional limited coverage across southern Alberta and southern Ontario/Quebec (the same domain as CIWS). During winter 2009, blending of the CoSPA forecasts and CIWS forecasts was accomplished, creating a transition from the two-hour CIWS forecast to the longer time scale forecasts of CoSPA.

The CIWS Program Office and CoSPA Program Office came to an agreement of formal demonstration with an operational evaluation during the 2010 convective season. A limited number of FAA facilities and airline operations centers (AOCs) were given access to CoSPA by integrating the forecast into the dedicated CIWS Situation Displays (SDs). A website was also provided, creating access to CoSPA for other users. Additional research is ongoing at MIT Lincoln Laboratory which takes the convective weather forecast along with studies of pilot behavior and translates them into Weather Avoidance Fields (WAFs). WAFs are helpful in identifying areas of reduced air traffic capacity (a NextGen initiative).

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