Meeting NextGen Weather ATM Integrations Goals, a Critique[i]

John McCarthy[ii]
Aviation Weather Associates, Inc., Palm Desert, CA 92211

Nicholas Stoer[iii]
Nicholas Stoer & Associates, Chester, MD 21619-2650

From 2003-2008, a group of scientists, managers, and engineers, including the authors, met at the Next Generation Air Transportation System (NextGen**)** Offices as the Weather Integrated Product Team (IPT). The team had been convened with the urging of Captain John Kern (retired from both FAA and Northwest Airlines) who was to become the first director of the Joint Planning and Development Office (JPDO). The IPT eventually became the Weather Working Group (2008 to date) of the JPDO. The team's objectives: (1) find solutions to reduce the 70 percent of delays attributable to weather; and (2) reduce the number of accidents and injuries in situations where weather is a leading factor.

A 2015-2025 weather vision that suited delay-reducing and safety-improving aspects of NextGen was created with this activity. NextGen weather capability improvements involved the efforts of the FAA, NASA, NOAA laboratories, NCAR, MIT Lincoln Laboratory, NWS, and DOD (Navy and Air Force). The Office of the President through the Office of Science and Technology Policy was also engaged. Critical to NextGen, the NextGen weather vision is a strong interagency focus of cooperation to maximize synergy across the broad array of capabilities that each agency possesses. The vision for NextGen weather focused on four major elements:

A. NEXTGEN WEATHER VISION

1. Improved weather observations.

This includes a broad adaptation of improved weather sensing to advance substantially capabilities for convective and winter storm analysis, development of a convective turbulence field from radar data and *in-situ* measurements of eddy dissipation rates from air carrier flights, detection of severe icing conditions including the presence of super-cooled liquid water equivalent using a multi-sensor approach, and improved use of satellites to detect national ceiling and visibility conditions between surface observation sites.

2. *Improvements in forecast science.*

While forecasts improved steadily in the last 10-15 years, the teams were looking to accelerate these advances. This focus led the team to the use of very high resolution CONUS-scaled numerical weather prediction models.[iv] Expert systems techniques integrate high-resolution sensor-based thunderstorm extrapolations with model based-forecasts on a 3-kilometer grid size out to 8 hours and beyond. Additionally emphasis is placed on evolving forecast systems to produce probability functions, in addition to deterministic products. The NextGen weather data will be populated with probability fields. As this work progresses, ensemble forecast techniques will be a critical component.

Several examples of this forecast approach have been developed. The high resolution CoSPA forecast model developed by a team of scientists from MIT Lincoln Laboratory, the National Center for Atmospheric Research and NOAA's Global Systems Division had a successful operational evaluation during the summer of 2010 at many FAA and airline locations. These capabilities allowed air traffic managers and airline dispatchers to assess the tactical (0-2 hours) and strategic (2-8 hours) decision-making utility of CoSPA. MIT is presenting a paper at the AMS annual meeting that discusses the 2010 CoSPA field evaluation.

Other successful examples of sophisticated forecasts are the Graphical Turbulence Guidance (GTG) and Forecast Icing Product (FIP) expert systems, both operating successfully at the National Weather Service, and accessible to the user on the Aviation Digital Data Service (ADDS) of NWS.

3. Development of a weather data cloud.

Cloud computing was emerging as a concept during the last decade based on advances by Google, Microsoft and others. This NextGen weather strategy bootstraps off of the cloud concept and combines observations, analyzed fields and forecast data into the NextGen 4-Dimensional Weather Cube. While not a pure "cloud", his data base would be a net-centric virtual concept allowing all users to apply web-enabled concepts for access. This effort is closely coupled to developing a core weather network-enabled dissemination capability to allow for ease of network transfer of data. (The FAA NextGen Network-Enabled Weather (NNEW) capability is already functioning in the laboratory.)

4. Integration of weather information from the 4D Weather Cube into aviation decision support systems.

The ultimate objective of NextGen Weather is the development of dynamic weather impact fields and their translation in such a way that Decision Support Tools can automatically reason about how to avoid weather impacts. All ATM operators, dispatchers, and flight crews would make full use of common weather information to improve the safety and capacity of the NAS based on these decisions support tools. The vision focuses on the notion that our work is not ultimately about the weather, but about moving aircraft from origin to destination with the greatest safety and maximum efficiency.

Unfortunately, the biggest problem with the first JPDO vision elements presented above is that they are all described in meteorological terms. They were not directly tied to seemingly obvious benefits to the aviation user, but instead depend on a difficult translation and integration process to achieve benefits. As a weather community, we try to tell our story in terms of improvements to meteorological skill but we do not describe quantitatively how we believe the information could be applied in the world of air traffic management. We need to find clearer ways to describe the practical IMPACTS (i.e. benefits) these advances can have on ATC CAPACITY, SAFETY, and REDUCTIONS in DELAYS. Unfortunately "met speak" does not play well with end-state users; concrete end-state user results do.

In this regard, we need be more inclusive of the end users of improved weather information – airline dispatchers, FAA traffic management coordinators, and pilots. The end users can help us better determine what works and what needs rethinking. They can help us understand the world they live in 24-hours a day. The CoSPA operational evaluation during the summer of 2010 made great progress in user understanding and acceptability, as did the continued refinement of in-flight turbulence and freezing in-cloud precipitation products. These efforts with the participation of operational users (Delta-Northwest, United, Southwest and others) have made solid contacts with end-state users in FAA and the airline/pilot community.

An example of a vision shortcoming associated with users involves the role of pilots in the use of weather avoidance fields. Recently, we heard from a senior technical pilot who raised concerns about (1) common situational awareness for weather in the cockpit that relies mainly on ground and satellite sensors, and (2) a missed opportunity to make the flight crew a node in NextGen, whereby input from the cockpit contributes to more efficient CDM decision-making in NextGen weather. The FAA Aviation Weather Group (AWG) Weather Technology in the Cockpit (WTIC) program is addressing the first objection, although the pace of WTIC work could be faster. The second issue, the aircraft as a node, is not yet being addressed, and represents difficult issues. For example, when ground-based radar and model derived convective forecasts (e.g., CoSPA) are seen differently from the cockpit, conflicts in flight path adjustments could arise. Steps to fast track WTIC and consideration of the manner in which NextGen takes into consideration differences in ground-produced Weather Avoidance fields for the cockpit would be useful program enhancements.

B. CURRENT STATUS OF THE VISION.

We are now some seven years into the start of NextGen planning. The purpose of this paper is to focus on the level of success to date of the NextGen Weather-enabled concept. Was coordination between agencies sufficient? Has the broad vision remained intact as the weather portion of NextGen evolved? What are the areas needing improvement in either science or interagency management and coordination? What are the impediments to obtaining a successful outcome in NextGen Weather? To a large degree, we believe that many excellent results have come to fruition in the past three years, as the vision has morphed into action by the FAA Aviation Weather Program, and by the NextGen Office at the National Weather Service. During 2010 the FAA Aviation Weather Services Group (AJW-47) was established, which should bring valuable expertise to the weather acquisition process of NextGen.

Figure 1 below is a significantly modified version of a concept figure developed by MITRE CAASD, the NextGen and Operations Planning Office, and the Aviation Weather Group, and represents the conceptual process of the production of weather information and its translation into impact on end state use.

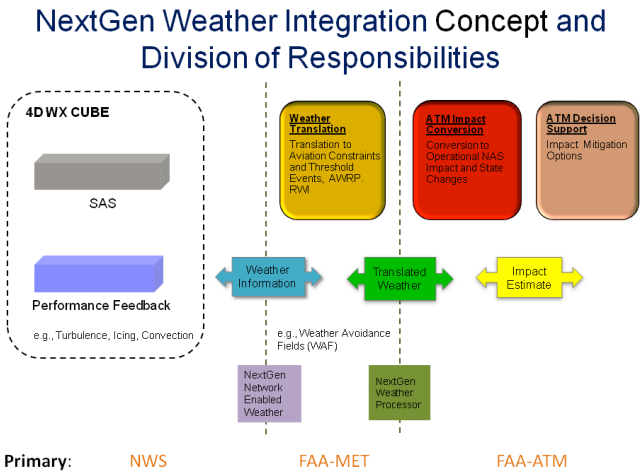

Figure 1. Production and translation of weather information to ATM Decision Support. This is a representation of much of the NextGen weather/Air Traffic Management Integration concept, flowing from the NWS 4D Weather Cube on the left, to the development of weather impact fields (mustard colored box), to ATM Impact Conversion to NAS Impact, and finally to ATM Decision Support and the establishment of impact mitigation options in the NextGen NAS (shown as catsup and orange boxes on the right). In fact, the beginning implementation of this flow chart represents an excellent articulation of Weather ATM Integration NextGen weather to date. All arrows shown are two-way arrows, to indicate critical feedback mechanisms. Also shown are two FAA NextGen weather efforts, the NNEW as the technology for real-time acquisition and filtering of information from the 4D Weather Cube, and translation of that weather information to impact information useful to decision support systems. To this latter end, each major NextGen weather element requires sufficient operational testing to insure user (AOC, ATM) acceptance. The vertical lines separate organizational responsibilities, but they are not meant to diminish strong communications between organizations in so doing the work. Also shown is the NextGen Weather processor (NWP), a yet to be a fully defined FAA data distribution system.

C. PROGRESS ASSESSMENT

During FY 2009 and 2010 there were many changes in the NextGen aviation weather concepts and programs at the FAA and NWS. New group managers and program managers were selected to oversee the new programs. To assess how well the programs were tracking with the NextGen weather vision the Aviation Weather Group director asked the authors to interview

program offices at MITRE CAASD, the FAA and the NWS and to integrate the results of our discussions. Programmatically, there are some "good news" stories. We also encountered opportunities for collaborative improvements, which, if undertaken, should help progress in FY 2011 and FY 2012. This part of the paper elaborates on these points.

ACCOMPLISHMENTS

National Weather Service has made significant progress in creating a NextGen culture and in advancing its 4D Cube logic and plans. They have held an "industry day" with the private sector to elaborate on performance specs, roles, technologies and concepts. Contract awards are planned for as early as FY 2011 depending on the final budget from Congress.

NextGen Net Enabled Weather (NNEW) Capability: In September 2010 an interagency team led by FAA and NWS jointly demonstrated the NNEW net-centric capability at the FAA William J. Hughes Technical Center. The team included personnel from FAA, NWS, NOAA labs, NCAR and MIT/Lincoln Lab. The demonstration moved data formatted with NNEW Standards (e.g. GML, netCDF-4) using OGC Web Services (i.e., Web Coverage Service and Web Feature Service). Approximately 300 different weather products including many from NWS were made available during the demonstration. The demonstration network used a direct connection between the FAA Telecommunications Infrastructure (FTI) and NOAAnet. Internet and Internet 2 were used as well. All of the activity occurring within the FAA infrastructure was SWIM compliant. This validated the feasibility and efficacy of the NNEW concept as a means for eventually moving advanced weather products seamlessly from the NWS 4D Cube directly through to FAA end user platforms.

NOAA and FAA Weather Architecture: In early 2010 NOAA hired a PhD. systems engineer to map the NOAA NextGen architecture to the FAA architecture and vice versa. That collaborative effort had not begun as of the time of the interviews in mid-summer although FAA-NWS architecture discussions were finally underway in December 2010. That joint effort must be given priority because it could clear up disconnects across agencies. This effort needs to include the DOD weather architecture as well. This is listed as an accomplishment in that it demonstrates that the agencies realize that the government needs integrated, multi-agency weather architecture as we move forward into the NextGen environment.

Consolidated Storm Prediction for Aviation (CoSPA): Prototype versions of a CONUS-wide CoSPA were utilized in an operational evaluation continuously from June through October 2010, around the clock, at more than a dozen FAA en route centers, the FAA Command Center, and multiple airline operations centers. A formal evaluation report is due in early CY 2011. Airlines and traffic flow managers informally reported being able to make re-routing and scheduling adjustments with greater confidence. Feedback from the users is helping the researchers tweak the models. Operational feedback will help the design of the processors needed to run CoSPA 24/7. This operational evaluation was funded with the NextGen Reduce Weather Impact (RWI) budget item and showed how research efforts can transition toward operations. It was a great highlight of NextGen weather capabilities for 2010.

"NextGen 101". In 2008 the National Weather Service, developed a "NextGen Weather 101" education campaign used throughout that agency. It had the full support of NWS Director and his senior management team. In contrast, there still appears to be only a modest understanding within some critical portions of the FAA about the breadth and depth of the NextGen Weather Vision. The NWS primer on NextGen can be found at http://www.weather.gov/nextgen/ng101.shtml and is very much worth examining in depth.

CONCERNS

Program Coordination and Integration: As any large bureaucracy or institution knows well, FAA knows it has many stakeholders influencing the direction of the aviation weather enterprise. This is challenging, to say the least. The FAA, in conjunction with the NWS, needs to develop a more effective coordination and integration of NextGen efforts that emphasizes the interconnectedness of each major element.

Legacy System Thinking: The introduction of new concepts is challenging. This involves advocating point–to-point legacy system architecture approaches to collecting and disseminating weather. The net-centric operations (NCO) concepts originally embodied in NextGen are having difficulty taking root. This could result in an expensive and extended transition period. It could lead to development of duplicative Weather Sources (e.g. NWS 4D Cube vs. FAA's NextGen Weather Processor (NWP):

FAA Acquisition Management System (AMS) and Architecture Shortcomings: Some program challenges stem from an FAA-centric Aviation Weather Architecture and Weather Roadmaps that do not clearly bridge out to NOAA and to DOD. Perhaps more than in any other aspect of NextGen, there are roles for NOAA and DOD in the design, collection, processing, dissemination and use of aviation weather products.

RECOMMENDATIONS

1. Interagency NextGen Weather Retreat – Reengaging the NextGen Weather Vision. As simplistic as this may seem, FAA and the NWS would benefit from a well-planned retreat to bring everyone working on aviation weather together for several days to reengage around the NextGen Weather vision. We believe the DOD should be a part of such a retreat.

2. There is a critical need to immediately evolve the Weather ATM Integration/Translation report into an executable plan. This plan is one of the best news items coming from NextGen, and is founded in a long process of meetings and a REDAC Subcommittee. It needs to solidify with schedules and significant funding to proceed. The most recent version is dated

September 2010, and entitled Joint Planning and Development Office (JPDO) ATM-Weather Integration Plan v2.0.[v] The plan is consistent with The Weather – Air Traffic Management (ATM) Integration Working Group (WAIWG) of the National Airspace System (NAS) Operations Subcommittee of the FAA's Research, Engineering and Development Advisory Committee (REDAC). The group conducted a twelve-month study in 2007 to examine the potential benefits of integrating weather and air traffic management. This should be an integral part of the NextGen Segment Implementation Plan (NSIP) currently being framed.

3. NOAA and FAA budget and program offices need to continue to coordinate their FY 2012 budget proposals. This is self-explanatory but is restated here for emphasis.

4. Weather Technology in the Cockpit (WTIC). This program should be fast-tracked to facilitate common weather situational awareness among the cockpit crew, dispatchers and the Air Navigation Service Provider (ANSP). They all need a single common picture. There is also a need for the ANSP to understand the pilot's view of hazardous weather features from the cockpit, which may be clearer and more relevant than features displayed in forecast products. Put institutionally, information from the flight deck crew and aircraft sensors need to be factored into the Collaborative Decision Making (CDM) models being contemplated for NextGen.

5. FAA should consider having NWS executive participation in the FAA Acquisition Management System (AMS) Joint Resources Council (JRC) process where NextGen weather systems are being considered. This would apply to NextGen weather concepts as well as programs that have shared architecture, performance and maintenance issues such as the Automated Surface Observing System (ASOS). This includes participation in the review and preparation of materials prior to JRC meetings. For reciprocity, FAA should have similar insight into NOAA/NWS decision-making.

6. Several National Research Council studies of Aviation Weather services have repeatedly made strong recommendations that the FAA appoint a single high level director/manager/Chief Atmospheric Scientist to be the focal point for aviation weather issues and programs, including training. In such an appointment, the various pieces of weather in ATO (AJP and AJN) and Aviation Safety (AVS) can be successfully, integrated, coordinated and managed. This position needs to be created and filled sooner rather than later.

E. CONCLUSIONS

The evolution of NextGen Weather is a successful work in progress. Weather/Air Traffic Management Integration planning has been exemplary. The successful operational evaluation of CoSPA at the System Command Center, many en route centers, and at a number of Airline Operations Centers is viewed positively, an evolution that should be continued with great enthusiasm. Turbulence modeling and real-time airborne in-situ eddy dissipation rate measurements from more than 200 aircraft bode well for decreasing the negative impact of turbulence injuries. It has the potential for better strategic air traffic management of turbulence-impacted airspace by determining more precisely portions of airspace that pilots would rather not ply.

In the course of examining the good news, we also found three prevalent challenges. A. Communication across the two FAA weather organizations and related organizations needs to be greatly enhanced. B. FAA organizations and MITRE CAASD need to communicate regularly and successfully with the National Weather Service, a communication process that needs consistency and oversight. C. FAA needs to redouble its efforts to assure that the net-centric concepts of the NextGen vision are fully embraced and adopted as legacy programs migrate to the 21st century.

The FAA has to decide more clearly the division of responsibility across the multiple organizations at FAA that deal with weather including MITRE CAASD. Coordination with the National Weather Service NextGen Office is improving and needs to become part of the fabric at FAA and vice versa. In other words, the 1995 recommendations from the National Research Council study entitled "Aviation Weather Services – A Call for Federal Leadership and Action", a study led by BGen. Al Kaehn (Ret.), are as relevant today as they were 15 years ago.

Lastly, it is no secret that the weather programs, and indeed, the broad scope of NextGen *in toto*, have been the focus of heavy scrutiny by congressional appropriations committees, the DOT Inspector General and the General Accountability Office during the second half of 2010. FAA is aware of these critiques. The coming 12 months will be busy months for officials and managers associated with these programs. Their success in addressing the issues raised by the oversight agents (OMB, GAO, Inspector General, and Congress) will be critical to continued investment in aviation weather capability improvements and progress toward the NextGen visions.

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[i] This is a preprint of paper number and title **PD1.2 Meeting NextGen weather ATM integration goals, a critique,** by John McCarthy and Nick Stoer, part of the Second Aviation, Range and Aerospace Meteorology Special Symposium on Weather-Air Traffic Management Integration, as part of the Second Aviation, Range and Aerospace Meteorology Special Symposium on Weather-Air Traffic Management Integration, which in turn is part of the American Meteorological Society 91st Annual Meeting, January 23-27, 2011, Seattle, Washington.

[ii] Aviation Weather Associates, Inc., Palm Desert, CA 92211, johnmicroburst@earthlink.net. Also Chief Scientist, Weather IPT at JPDO, 2002-2007.

[iii] Nicholas Stoer & Associates, Chester, MD 21619-2650, nstoer@prodigy.net

[iv] The developmental High Resolution Rapid Refresh (HRRR) Model of NOAA Global Systems Division (GSD is used to support CoSPA.).

[v] Lead Author - David Pace in the AWG.