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AWIPS BUILD 5 IN REVIEW

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1. INTRODUCTION

The Advanced Weather Interactive Processing System (AWIPS) was deployed in 1999 and commissioned in 2000. AWIPS software release 4.2, the Commissioning Load, was considered to be the minimum capability to enable the transition from Automation of Field Operations and Services (AFOS) to AWIPS operations. Before completion of the commissioning load, the National Weather Service (NWS) began planning the first follow-on AWIPS software build to complete partially implemented functionality, fix problems noted during deployment, and implement new features. These changes were needed to significantly enhance the utility of the AWIPS for the Weather Forecast Offices (WFO) and River Forecast Centers (RFC). While the initial system provided the needed functionality to satisfy many modernization objectives, technology allowed for further improvements in information processing capabilities. National labs and universities continue to use advancing observing technologies to develop forecasting and warning algorithms that enhance the forecasters' ability to achieve even greater improvements in providing forecasts and warnings to the public. The NWS planned additional software builds to accommodate these advances.

The AWIPS program manager documented the Build 5 functional requirements, and in 1998, the Deputy Under Secretary for Oceans and Atmosphere, validated NWS' plans and requirements for this build through an independent review by a panel of external experts. The review team concluded in their report (Ladwig, et al, 1998) that completion of Build 5 was essential to the core mission of the NWS to provide weather and flood warnings, public and marine forecasts, and advisories for the protection of life and property. The planned increase in capability provided by each module implemented in Build 5 was designed to increase forecaster efficiency and assure one WFO could back up another WFO during a catastrophic outage. Further, Build 5 capabilities would allow the forecaster to assimilate critical weather radar information with weather satellite data, assuring state of the art forecasting techniques and emerging severe weather forecasting tools were placed into operations in the WFO. The NWS received $25M over 3 years to accomplish this build.

This paper reviews the entire Build to reflect how the system moved to a different level of operational effectiveness over the past 3 years to its current state. It begins with an overview of the build and highlights of the development process and describes key functionality implemented and its impact on the NWS forecast process or our customers.

2. BUILD 5 OVERVIEW

For the past 3 years, the AWIPS Program focused on implementing the following core Build 5 functionality:

a. Product preparation improvements such as a fully capable Interactive Forecast Preparation System (IFPS) for automatic generation of digital, graphical and textual forecast products, and improved long and short term watch and warning capabilities, and graphical displays comparing

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forecasts and observations;

b. Decision assistance tools such as the System for Convection Analysis and Nowcasting (SCAN) and Flash Flood Monitoring and prediction (FFMP) which provide radar monitoring capability and warning decision support information in graphical and tabular format;

c. WFO Hydrologic Forecast System (WHFS) which provides short term forecasts of river systems;

e. NWS River Forecast System (NWSRFS) which implements stage III hydraulic modeling requirements;

f. Updated Weather Forecast Office - Advanced (WFO-A) functionality, including improvement of the NEXRAD radar interface, ingest and display of new model guidance and satellite products, and improvements to the system infrastructure, such as message handling and product receipt notification;

g. Improvements to Local Data Acquisition and Dissemination (LDAD) to enable data exchange with other agencies;

h. Improvements to enable display of national scale data necessary for National Centers, Alaska and Hawaii, and to implement the National Center NMAP functionality in AWIPS.

Build 5 was partitioned into five smaller releases, 5.0, 5.1.1, 5.1.2, 5.2.1, and 5.2.2. AWIPS software was developed by the Forecast Systems Laboratory, Office of Science and Technology (OS&T) Meteorological Development Laboratory (MDL), National Centers for Environmental Prediction (NCEP) Central Operations (NCO), Office of Hydrologic Development (OHD) Hydrology Laboratory, and OS&T Systems Engineering Center (SEC). The system integrator was Northrop Grumman Information Technology (NGIT). Each development organization was supported by their support contractors, including RS Information Systems (RSIS), Science Applications International Corporation (SAIC) and Raytheon. Although requirements for Build 5 were established very early in the program, user feedback regarding functionality and performance was provided by the NWS Office of Climate, Water, and Weather Services as well as the AWIPS Focal Point from each NWS region.

2.1 Product Preparation Improvements.

Several changes were made to implement new techniques for the NWS forecaster to prepare products for distribution to customers. A primary purpose of Build 5 was to complete the Interactive Forecast Preparation System. In Release 5.0, the Interactive Computer Worded Forecast (ICWF) and AWIPS Forecast Preparation System (AFPS) software were merged into a single, grid-based Interactive Forecast Preparation System (IFPS). IFPS represents a substantial change to how forecasts are prepared and disseminated. Forecasters no longer have to type text forecasts tailored for specific user communities (e.g., public, marine). With the IFPS, forecasters prepare graphical depictions of predicted weather, using interactive displays of initial forecasts. With tools like the Graphical Forecast Editor Suite (GFESuite), forecasters can initialize and edit grids of forecast weather elements (e.g., maximum and minimum temperatures, wind speed and direction, and amount of cloud cover). These grids make up a common digital database which is used by product generation tools to automatically compose and format a suite of routine public, marine and fire weather forecast products for the National Oceanic and Atmospheric Administration (NOAA) Weather Wire Service (NWWS) and NOAA Weather Radio (NWR). (Ruth, 2002) These products include:

- Zone Forecast Products (ZFP)
- Coded Cites Forecast (CCF)
- Service Area Forecast (SAF)
- Tabular State Forecast (TSF)
- Coastal Waters Forecast (CWF)
- Marine Verification coded Forecast (MVF)
- NearSHore Forecast (NHS)
- Great Lakes open lake Forecast (GLF)
- Fire Weather Forecast (FWF)
- Miscellaneous Fire Weather prediction (FWM)

A service backup capability that allows a WFO to support operations of an adjacent office by sharing backup configuration information among offices was added for Release 5.2.2. Whenever a site is unable to issue its routine operational suite of forecast products, a different site (i.e., a backup site) may initiate the Service Backup program and begin generating and issuing a routine operational suite of forecast products for the failed sites.

The GFE Suite has been revised to the point where it has a suite of hydrometeorological algorithms known as smart tools. Smart tools are user configurable routines that take gridded output from Numerical Weather Prediction Models and create an initial field of forecast weather elements. After editing, this set of gridded weather elements describe the expected weather conditions for the forecast period. By capturing the forecast as a set of grids, a wide variety of products can then be generated automatically. An infrastructure for generating text and graphic products from these forecast grids has been developed. This has allowed sites to generate new experimental products as well as the standard set of NWS text products.

IFPS will free the forecaster from typing several text messages that describe the same weather for different clients. In times of severe weather, IFPS largely frees forecasters from preparing routine products, letting them concentrate on watches and warnings. The IFPS approach ensures consistency among all forecasts supporting different services for the same area and time. The existence of a gridded database of forecast weather elements will permit automatic monitoring of incoming weather observations, alerting the forecaster to observations which differ significantly from the current forecast. The forecast database will support enhanced verification procedures, and resolution of differences in forecasts at the boundaries between offices. IFPS graphical displays and tools can be used to create highly detailed, graphical, text, voice and tabular products will be very easy. The digital data are transmitted in GRIB2 format to a National Digital Forecast Database (NDFD) where a seamless mosaic is produced for the entire country. This NDFD will be used to produce products that offer high resolution and maximum flexibility to customers and partners.

The Watch, Warning, Advisory, and Statement (WWA) application enables the user to create, modify, and maintain watch warning and advisory products. After creation, the forecaster may follow up, clear, or cancel the statement within the WWA application. The WWA application within IFPS is used for long-fused hazards. In addition, any product produced using WWA is formatted for transmission to NOAA Weather Radio (NWR).

During Build 5, WWA was enhanced to support WWA marine and fire weather capabilities, intersite coordination of hazards for coordination and monitoring purposes, Watch Decentralization - Phase I, and the Voice Improvement Processor (VIP), the new voice for NWR. Also, enhancements were made to improve the usability of user interfaces.

The climate software was enhanced to prepare monthly, seasonal and yearly climatalogical summaries based on incoming observations and climatic records in the AWIPS database. Reports are now formatted for the NWWS and for the NWR. The software was enhanced to include daily products in the Build 5 time frame.

The Aviation Forecast Preparation System (AVNFPS) allows forecasters to create/edit and amend Terminal Aerodrome Forecasts (TAF) and TWEBs and performs a verbose and complete error checking based on NWS Operations Manual Chapter D-31. The AVNFPS provides an automated monitoring capability where the current TAF is continuously monitored against the observations. The forecaster can monitor TAFs by looking at color coded alerts, bar graphs of TAF and Metars, and a standard presentation of Metars and TAF. The AVNFPS allows for local airport specific amendment criteria to be entered into each TAF for monitoring and amendment purposes. It even has a feature for computing crosswinds at each airport and alerting the forecaster when that criteria are met.

2.2 Decision Assistance Tools

Release 5.0 was the first delivery of the System for Convective Analysis and Nowcasting (SCAN). SCAN is the result of a collaborative effort involving the NWS, the National Severe Storms Laboratory (NSSL), and the National Center for Atmospheric Research (NCAR). The focus of SCAN is on improving the accuracy and timeliness of warnings (severe thunderstorm, tornado, flash flood, etc.) issued by NWS forecasters, through the development of automated warning guidance. SCAN detects, analyses, and monitors thunderstorms and generates short-term forecasts and warning information for severe and tornadic thunderstorms and flash floods.

SCAN provides rapid access to radar cell, mesocyclone (MESO), and tornado vortex signature (TVS) information in the form of tables. It automatically ranks and sorts cells, MESOs, and TVSs based on severity or other user specified criteria. It also allows users to zoom from tabular information on a particular cell, MESO, or TVS to features on the AWIPS Display 2 Dimensions (D2D). The user can request a time trace (trend) of any relevant cell, MESO, or TVS parameter. The user can set rate-of-change alarms for any relevant parameter. Also, an index which automatically determines the level of severe weather and flash flood threat for a given County Warning Area (CWA). This capability explicitly couples central and local guidance (End-to-End Forecast Process) and enhances the forecaster's situational awareness.

The Flash Flood Monitoring and Prediction (FFMP) system is an integrated suite of multi-sensor applications which detects, analyzes, and monitors precipitation and generates short-term warning guidance for flash flooding automatically within AWIPS. The resolution of the hydro-geographic base data on which the hydrometeorological analyses are conducted are on the order of 2 to 10 square miles. FFMP provides forecasters with accurate, timely, and consistent guidance and supplement forecaster event monitoring with multi-sensor, automated event monitoring. (Filiaggi, et al., 2002)

2.3 Hydrologic System Changes

The five software releases that constituted AWIPS Build 5 provided many significant advances in the application tools used by NWS field offices to conduct the NWS Hydrology Program. The Hydrology software is divided into components that are delivered to all field forecast offices and components that are delivered only to RFCs due to their unique hydrologic modeling needs. The major software components delivered to all field forecast offices include the Integrated Hydrologic Forecast System (IHFS) relational database, the WHFS, the hydrology precipitation processing subsystem, and the SHEF Decoder. During Build 5, many performance and usability enhancements were added in addition to new functionality for the forecasters in the WFOs and the hydrologists in the RFCs. (Glaudemans, et. al., 2002)

2.3.1 WFO Hydrologic System Changes

A summary of significant improvements made to these common WFO and RFC components include:

a. Improved performance of all applications due to structural improvements in the IHFS Database.
b. Support for SHEF vector data types was added to the database and the SHEF Decoder.
c. The addition of an entirely new time series graphical and tabular display application to the WHFS that provides robust graphical and textual editing capabilities for all environmental data, and the ability to create pre-defined user customized scenarios for routine data review.
d. The re-implementation of the WHFS HydroView application on a new set of geographic mapping software that uses more mapping data sets common with the core AWIPS display, D2D, configures mouse actions much like D2D, and provides more data display options for the user.
e. The addition to WHFS HydroView of a revised point data plotting control with far more flexibility and intuitive appearance, computation of precipitation accumulations on-the-fly, a new tabular point data display that complements the map display, features and controls to allow WFOs to provide Service Backup for neighboring WFOs, and the ability to derive river flows from stages and vice versa using river rating curves.
f. The addition to the WHFS of the Site-Specific Hydrologic Prediction Function (SSHP) which is a simple hydrologic model to be used at WFOs to model river rises and potential flooding at the outlet points of headwater basins which respond quickly to heavy rainfall.
g. The addition to WHFS RiverPro of the ability to support Valid Time Event Coding (VTEC) in products (targeted at external users such as emergency managers and the media), the ability to create products that are segmented by river basin or groups of river stations, the ability to include metric units and English units in products, the ability to tailor product contents by time zone, and the ability to invoke the WHFS Time Series application for data review.
h. The addition to the SHEF Decoder and to the WHFS of robust new data quality control functions and displays that check data values against gross range limits, check data values against reasonableness range limits, check time series data against rate-of-change limits, provide various displays for interaction with good, questionable, and bad data, and provide the ability to select corrected station observations and forecasts and encode them in SHEF to send on the AWIPS Wide Area Network (WAN) to one or more field offices that need them.
i. The addition to the SHEF Decoder and to the WHFS of the new ability to alert and alarm the forecaster when incoming data values or their rates of change exceed pre-set thresholds.
j. The delivery of the Multi-Sensor Precipitation Estimator (MPE) application to all WFOs whose graphical user interface has been integrated into the WHFS HydroView application. The MPE was implemented first for the RFCs and then later was

implemented for the WFO AWIPS interface. The MPE integrates radar rainfall data from several nearby radars with rain gauge data and satellite data to prepare the best quantitative precipitation estimate (QPE) for a particular region. It also computes the mean field bias (at various time scales) of the radar precipitation accumulation products using rain gauge data and sends those bias values back to the associated NEXRAD Radar Product Generator (RPG) for use in correcting many of the RPG precipitation products seen in D2D and used by external customers.

k. The initial national delivery of an updated WHFS Dam Catalog application (in AWIPS Release 5.2.2) originally developed by the Colorado Basin RFC and ported to AWIPS.

l. An updated SHEF Decoder, the primary data ingest processor for the IHFS Database via structural changes in the application.

2.3.2 RFC Hydrologic System Changes

The major software components delivered to the RFCs include the NWS River Forecast System (NWSRFS) including the Operational Forecast System (OFS), the Interactive Forecast Program (IFP), and the data pre-processors, the Ensemble Streamflow Prediction (ESP) system; the model Calibration System (CALB) including the Interactive Calibration Program (ICP0), the RFC Forecast Verification system (Verify), the Interactive Double Mass Analysis (IDMA) program, and Data Analysis and Interaction program suite. A summary of significant improvements made to these components include:

a. Implemented a data analysis and interaction suite of programs that was originally developed by the Arkansas Red River Basin RFC and then ported to AWIPS for national implementation.
b. New displays within the IFP for model states for several hydrology customers supporting the Sacramento Soil Moisture Accounting (SAC-SMA) model and the SNOW-17 model.
c. New time series display graphical user interface for IFP to provide users with the ability to display multiple data types in a single window interface (up to 10 different data types in up to six window panes).
d. New model operation in OFS for use with reservoir modeling which permits users to create a time series and fill it with a pre-specified value.
e. The addition of the Kolmogorov-Smirnov (K-S) statistic to the Interactive Verification Program.
f. A new mean areal precipitation (from radar) data pre-processor for CALB.
g. Two new programs for the ESP, an ensemble pre-processor calibration program and an error model calibration program.

2.4 Radar Interface

As part of release 5.2.1, a new TCP/IP LAN-based interface between AWIPS and the Weather Surveillance Radar 1988-Doppler (WSR-88D) Open Radar Product Generator (ORPG). While ultimately intended to replace the legacy X.25 interface, the TCP/IP LAN software was designed to run concurrently with the legacy software, to facilitate the transition of AWIPS-RPG connections from serial X.25 to TCP/IP Ethernet, and to permit continued support for radars which will not be upgraded in the near term (non NWS radars). The new interface has proven to be extremely stable, and can support much higher data transfer rates between AWIPS and the RPG (10Mbps for TCP/IP, versus 56Kbps). As a result, AWIPS can now receive larger, higher resolution products generated by ORPG Builds 2 and beyond.

As part of the Build 5 development, AWIPS replaced the WSR88D Principal User Processor (PUP) as the system for displaying and interacting with radar data, and with the introduction of the Open RPG, high resolution (256 level) products were made available to the forecaster. Appropriate changes have been made to the AWIPS display code to handle these new products. Also, an extended inventory capability was added specifically to handle multiple WSR88D request products. For example reflectivity and velocity cross sections using different baselines can be generated during the same volume scan. In this case, an additional parameter (such as baseline endpoints) is needed to differentiate the products. The AWIPS inventory function was expanded to include additional fields for this purpose.

The MPE application implemented for Hydrological analysis resulted in a rainfall bias table for transmission to the RPG to use in calculating rainfall estimates. The new TCP/IP interface facilitated completion of the precipitation estimation improvement. Also implemented is a new radar echo classifier which will give forecasters indication of clutter likelihood. Finally, we have implemented a compressed product of base reflectivity and velocity for distribution to NCEP where they are implementing the capability to initialize one of the models with base radar data.

2.5 New Data Sets

As AWIPS has become operational, it has had to deal with a continuous flow of additions and changes to the data stream. During Build 5, the ability to easily add and modify data sets in AWIPS was significantly improved. A more generic approach for storing and retrieving data in netCDF was implemented, eliminating the need for individual routines for each different data set. The basic paradigm for displaying point data was revised around a concept known as design files. This allows local users to specify which fields are displayed and their location in a station model plot. Multiple design files can be written to accommodate individual tastes or specific needs. As new point data sets are added, they automatically tie into this capability eliminating the need for additional code to display new point data.

The advent of the Open RPG opened the door for new radar products. The infrastructure controlling radar data and products was reworked based on a configuration file approach common within AWIPS. New radar products can now be added by simply modifying appropriate text files and running a localization.

One of the standard data formats used within the WMO for data exchange is BUFR. Many point data sets are encoded in this format. A generic BUFR decoding structure was implemented in Build 5. This eliminates the need for a separate new decoder as BUFR data sets are added in AWIPS. By specifying some metadata, a new set of BUFR encoded information can be added to AWIPS.

2.6 Local Data Acquisition and Dissemination (LDAD)

An enhancement to the dissemination component of the LDAD, a subsystem within AWIPS, was implemented during Build 5. Known as the Emergency Management Dissemination System, it provides tailored graphic, image, text, and gridded weather information. It combines weather information from the local WFO, GIS information from the local client's computer, and action rules from the emergency manager's warning plans to generate a set of displays. These displays present condensed, coherent information for the emergency manager.

2.7 NMAP

NMAP is the primary application used at the NCEP service centers to generate graphical forecast products. The program supports the production of NCEP graphical products by providing the following set of capabilities:

- Global meteorological data access and display on user-defined geographic scales and map projections;
- Meteorological object drawing and editing;
- The production of graphical products integrated with data display; and
- Graphical production product pos-production into formats including GIF, TIFF, PostScript, AWIPS RedBook and Fax.

Graphical products generated by NMAP at NCEP service centers include aviation significant weather charts, surface analysis and forecast charts, outlook and watch products, and marine charts.

NMAP has been integrated into the AWIPS environment as a baseline AWIPS application available in release 5.2.1 to support the production of graphical products in Alaska and Pacific Regions. These regions share many of the same product generation requirements as the NCEP service centers thus making NMAP a logical choice in meeting these requirements at their sites. NMAP supports the production of marine, surface and aviation products at these OCONUS sites. In addition, NMAP is used to support the generation of "seamless" graphical products between NCEP services centers and OCONUS sites.

NMAP is also deployed at RFCs to support the Quantitative Precipitation Forecast (QPF) Program requirements. The RFCs use NMAP to modify graphical QPFs generated by NCEP's Hydrometeorological Prediction Center (HPC) and generate grids as input into hydrological models.

3. SYSTEM ARCHITECTURE CHANGES

Although there may not be a recognizable effect of system architecture changes, these changes may be of interest to folks who follow the system's evolution or who are merely curious. Briefly described here are changes to the compiler, software installation and customization, and database management.

One of the most important decisions regarding AWIPS evolution was made early in the Build 5 development period. AWIPS had been developed using HP-UX and proprietary compilers provided by Hewlett-Packard. Rather than continue on a proprietary path, the decision was made to migrate to an open compiler, gcc. This would provide more rigor in checking the code for compliance with open standards. More importantly though, gcc is available on a wide variety of platforms and operating systems. This decision made it possible to port AWIPS to the Linux operating system. (Piercy, et. al., 2002) That evolution reached its first milestone in Build 5.1.2 when the basic D2D workstation was implemented on a Linux personal computer (PC). This new, higher capacity workstation improved performance, especially product load times, and provided room to grow. The next step was upgrading the Satellite SBN Communications Processors (CP) on site to a Linux-based server capable of data storage and increased throughput on the order of 4 T1 lines. These CPs, when coupled with the Linux-based SBN uplink servers in place at the NCF, will allow the data of the future to flow to the sites.

Because sustained or improved performance remains a priority for AWIPS, additional Linux-based servers are planned to replace or augment existing WFO and RFC hardware. This technology infusion, made possible in part due to the decision to use the gcc compiler, will allow AWIPS to exploit new and expanded weather data in support of the NWS's mission.

One of the strengths of the AWIPS design is its concept of customization. With more than 130 WFOs and NCEP Service Centers scattered across the USA, it was vital that AWIPS accommodate unique local operational needs. One of the mechanisms for satisfying this requirement was to allow sites to customize various tables, templates, and other configuration files used by the system software. However, prior to Build 5 customization became problematic; AWIPS upgrades would often overwrite site-customized files, leaving the system in an unexpected state. It would sometimes take longer for a site to recover from the upgrade than to perform the upgrade itself. The solution involved a new tool called the Installation & Customization Automation Tool (ICAT), prototyped during Releases 5.1 and 5.2, and finally delivered to all sites as part of 5.2.2. ICAT identifies previously customized files which will be overwritten during the system upgrade, and automatically merges newly delivered files with existing customized versions. ICAT saves the file away until the system upgrade is complete. After the upgrade, site personnel invoke the post-installation component of ICAT to activate the merged files by pushing them to their target operational locations and initiating localizations as necessary.

In release 5.0, the AWIPS Program implemented an important change to the text database which is used to store all text products, including official forecasts as well as products generated for local storage only. Text products distributed offsite and broadcast to other WFOs often end up in the text database at some or all sites around the country. Prior to Build 5, these text products were stored and retrieved via their nine-character product id, more commonly referred to as the "AFOS PIL", a legacy from the pre-AWIPS system. The AFOS PIL format was not used on products originating from some external agencies, who only generated products with the World Meteorological Organization (WMO) communications header and no AFOS PIL information. Such products could only be stored or retrieved by using derived AFOS PILs, which was often problematic due to the many-to-one relationship between AFOS PILs and WMO ids. Implementation of WMO ids in the new text database scheme now permits products with no associated AFOS PIL to be stored and retrieved via their original WMO ids, without the need to generate an AFOS PIL.

4. BUILD 5 SUMMARY

Build 5 enhanced the forecaster's ability to identify severe storms and floods and to rapidly issue warnings, increased forecaster efficiency through development of interactive tools like the IFPS, and introduced and enhanced both the warning and efficiency efforts at OCONUS sites. Emphasis was placed on IFPS, ORPG connectivity, warning tools, and OCONUS support. The biggest change in the NWS forecast process wrought by Build 5 is the move toward preparing and disseminating new graphical and digital products. From the forecaster's perspective, IFPS changed the way WFOs prepared forecasts and disseminated products. With IFPS, forecasters began using a new interactive process to prepare their forecasts. They are now interacting with visual meteorological fields while working within the common digital database. For the first time, the forecaster has been able to control the forecast process. They can manipulate the models and incorporate their own methodologies and expertise into the forecast. As a result, the value of our products to our customers and partners will dramatically increase.

Build 5 was the initial round of changes to AWIPS to meet mission needs and infuse new technology. As data requirements grow, the platform must necessarily evolve with new technology. With technological improvements, new capabilities will arise which capitalize on the available technology. The AWIPS Program is aware of the need to continue to infuse new science and technology into the system to improve AWIPS' data management, storm identification and warning capabilities, and support for OCONUS sites. The continued Linux migration will drive stability and performance improvements into the system as it evolves over the next 5 to 10 years.

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