Report on an Analysis of FEWS Software and Recommendations for Integrating CHPS/FEWS With AWIPS II

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Acronyms and Abbreviations Used in This Report

AWIPS	Advanced Weather Interactive Processing System
CAVE	Common AWIPS Visualization Environment
CHPS	Community Hydrologic Prediction System
EDEX	Electronic Data Exchange System
FEWS	Flood Early Warning System
FSS	Forecasting Shell Server
GUI	Graphical User Interface
IHFS	Integrated Hydrologic Forecast System
IOC	Initial Operating Capability
MPE	Multi-sensor Precipitation Estimation
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
NWSRFS	NWS River Forecast System
OHD	Office of Hydrologic Development
OpenMI	Open Modeling Interface
RFC	River Forecast Center
SOA	Service Oriented Architecture
WFO	Weather Forecast Office

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1.0 Overview

1.1 Background

The River Forecast Centers (RFC) of the National Oceanic and Atmospheric Administration's National Weather Service (NOAA/NWS) have relied on the NWS River Forecast System (NWSRFS) since the 1970s to supply the hydrologic models and data handling systems they use to generate river forecasts and water resource information. Over the years, NWSRFS has grown and changed, gradually adding a diverse set of capabilities and increased functionality. Along the way, the NWSRFS software has been ported to various hardware and operating system platforms, and today it runs as a major subsystem within the Linux-based Advanced Weather Interactive Processing System (AWIPS) at all 13 RFCs.

Today's NWSRFS software is large and completely customized. It is also difficult to maintain, difficult to enhance, and costly to service. As such it cannot meet the burgeoning needs of the current hydrometeorological community focused on the introduction of new scientific techniques, and the development of a replacement system known as the Community Hydrologic Prediction System (CHPS) is now in progress. The CHPS infrastructure will house most of the existing capabilities of NWSRFS as well as new scientific techniques, and it will be significantly more flexible and maintainable than NWSRFS.

The NOAA/NWS Office of Hydrologic Development (OHD), which is developing CHPS, has determined that the Flood Early Warning System (FEWS) shows great promise as a software infrastructure for CHPS. FEWS has been operational within the European hydrologic community for several years, and a "CHPS FEWS Pilot" system was successfully demonstrated at two RFCs in April 2007. At this point FEWS is expected to form the basis of a CHPS initial operating capability (IOC) targeted for operational deployment in mid-2009.

At the same time that the CHPS/FEWS research and development effort has been under way, Raytheon, under contract with NOAA/NWS, has been leading an AWIPS modernization initiative – AWIPS II. AWIPS II is based on a Service Oriented Architecture (SOA). Raytheon has already begun to introduce the new SOA-based infrastructure and re-engineer existing AWIPS functionality into AWIPS II. One of the later phases (Task Order 10) of AWIPS Migration will include NWSRFS.

Although NOAA/NWS does not intend to integrate the CHPS/FEWS IOC into the first release of AWIPS II, the goal is to achieve a future integrated solution using AWIPS II and FEWS to meet overall requirements defined by OHD. The current AWIPS II plan identifies a single point of interface between the NWSRFS modeling functionality and the rest of AWIPS II. This interface is described as an Electronic Data Exchange System (EDEX)-based "HydroSrv" component. Hydro visualization is expected to be part of the Common AWIPS Visualization Environment (CAVE). Interfaces between these AWIPS II components and the CHPS software must be defined before CHPS development has progressed too far.

1.2 AWIPS/CHPS Interface: Task Scope

In July 2007, NOAA/NWS engaged Raytheon to investigate, at a conceptual level, the AWIPS II/FEWS interface. The scope of Raytheon's task was threefold:

1. Analyze the CHPS/FEWS pilot software to determine the best (i.e., most cost-effective) approach to integrating FEWS into RFC operations based on the AWIPS II architecture;

2. Make high-level recommendations for a design approach to implementing CHPS as an extension to, or a component of, the AWIPS II software baseline; and

3. Develop an approach that allows AWIPS II and FEWS deployment to occur with minimal impact of one project on the other.

1.3 In This Report

Raytheon is pleased to present the results of our CHPS/FEWS analysis in Section 2.0 of this report, and to outline our recommended design approach to integrating AWIPS II and CHPS/FEWS in Section 3.0. Section 2.0 provides a brief description of our approach, key features of FEWS that are relevant to this analysis, and a summary of the results of our current-state assessment. In Section 3.0 we present our recommendations in detail. No cost estimates for follow-on development tasks are included in this report.

1.4 Reference Documents

Mule ESB (Hohne, Gregor & Woolf, Bobby: Enterprise Integration Pattern)

Delft FEWS Published Interface (Delft Hydraulics, Version 2.5, 21 March, 2005)

2.0 FEWS Analysis: Approach, Results, and Conclusions

Raytheon engaged with Delft Hydraulics, maker of FEWS, and CHPS architect Apex Digital Systems to gain a better understanding of the CHPS project. We also participated in Technical Interchange Meetings with NOAA/NWS, where we learned more about the existing CHPS pilot demonstration and FEWS interfaces. Then, with assistance from Delft and the use of Delft-provided source code, we analyzed the FEWS software, and identified potential points for the integration of CHPS/FEWS into the AWIPS II software baseline for:

- Input data requirements, including User Interface control, format and delivery
- Data output, including possible User Interface options, format and storage options
- Data visualization capabilities, including User Interface options and format
- Model execution management requirements, including User Interface options.

In this section, Raytheon identifies key features of FEWS relevant to our analysis, and currently projected interface points with AWIPS II. Also presented are the results of our assessment of the current state of FEWS/AWIPS integration and a listing of the potential points of FEWS/AWIPS integration identified during the performance of this task order.

2.1 FEWS Key Features and Interface Points

FEWS is based on an open architecture and uses the European Open Modeling Interface (OpenMI) standard.[*] Its "core" system provides libraries and utilities developed to meet the common needs of hydrologic forecasters around the world; specific hydrometeorological applications are developed and maintained by the originators as "plug-ins" to the basic system.

The main components of FEWs include the J2EE Application Server and Master Controller; the Forecasting Shell Servers (FSS); the Operator Client; and the Admin Interface.

- *J2EE Application Server & Master Controller.* The Master Controller sits at the heart of a distributed setup of FEWS, and controls the communication between the various system components. Raw and processed data and forecast products are stored in the system cache called "Central Database." The Central Database also stores the FEWS configurations.

- *Forecasting Shell Servers.* These servers are the processing engines of the system. The Master Controller schedules import workflow on them. The forecasting workflows (including the data processing and running of sequences of models) are also run on the FSSs.

- *Operator Client.* The FEWS Operator Client controls user access. This map-based graphical interface is typically meant for use by forecasters in an RFC. It provides the specific functionality required to (interactively) operate the river flow forecasting system.

- *Admin Interface.* The Admin Interface provides access to the FEWS back end and is typically meant to be used by system managers.

The FEWS FSS will interface with the AWIPS II system by receiving weather forecast, telemetry system, and radar data from the AWIPS II data stores. This may be "on demand" or by subscription service. A FEWS FSS will also provide data (actively or passively) to the AWIPS II data stores for external storage and possible use by other applications.

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[*] Note: Java support for OpenMI has been dropped as of May 2007; only the .NET version is being maintained.

2.2 Current-State Assessment

Although the AWIPS II delivery will radically change much of the data ingest, storage, exchange, and display of the NWS AWIPS system, changes to the OHD database schema are expected to be minimal. FEWS is a COTS product, which provides an advanced infrastructure for Hydrological Model applications. Pilot efforts to integrate the FEWS infrastructure into the business flow of the RFCs are already under way and will continue into the near future. Because these efforts may provide valuable information about the future concept of operations of the AWIPS II/CHPS/FEWS environment and its ramifications for the technical environment, and potentially some reusable code as well, the impact to these efforts during the transition from AWIPS I to AWIPS II must be carefully evaluated and planned.

Fortunately, FEWS operates within a web-centric architecture, supports messaging and JAVA plug-in technologies, and is largely compatible with the AWIPS II architecture. Our evaluation suggests that extensions to AWIPS II would be able to support the key integration points required to support FEWS-AWIPS II interfaces, as well as other client applications. The general pattern that would support these extensions is already planned for AWIPS II. Some additional modifications may be needed; these would require relatively small additional plug-in or micro-engine development to support specific data formats. In addition, the Delft engineering team has suggested a few general-purpose extensions to FEWS that would facilitate a more seamless integration of the two systems. Examples of these extensions include ingest of data in HDF5 format, JMS message communication with AWIPS II, and export of data from the FEWS cache.

Raytheon does not anticipate significant modifications to the Graphical User Interfaces (GUI) of either CAVE or FEWS. CAVE will provide the GUI necessary for the Weather Forecast Offices (WFO) (with capabilities consistent with the current AWIPS I) while FEWS will support the RFCs. Extensions may be made to either system as future requirements dictate. Raytheon and Delft recommend that these two environments remain separate even as modifications may be made to support future needs.

2.3 Key Integration Points

The Raytheon FEWS Analysis identified four potential integration points between AWIPS II and FEWS. They are generally based on data exchange, user or automated controls, and visualization of data. These integration points are:

- *Data Delivery.* FEWS will need input data from AWIPS II-managed data stores to support capabilities that are currently supported in pilot studies and future plans.
- *Data Ingest.* FEWS or FEWS-managed model output data may eventually be stored in an AWIPS II-managed data store.
- *Data Visualization.* Visualization of forecast products (generated by FEWS) within the CAVE environment could require some integration.
- *Process Controls.* Control of the bidirectional data flow is also highly desirable.

2.3.1 Data Delivery

Integration of the FEWS product with the AWIPS II architecture would first involve transfer of data *from the AWIPS II data repositories to the FEWS data cache.*

The current NWS OHD pilot study uses a CRONTAB-initiated Java application for extraction of data from the IHFS data repository, with data converted to an XML document according to the published FEWS interface schema. Radar data in GRIB1 format is also being ingested by the FEWS pilot implementations.

The current plan for the AWIPS II Continuous Technology Refresh (CTR) does not include changes in the IHFS database schema or the Multi-sensor Precipitation Estimation (MPE) GRIB 1 radar products; therefore, the approach described here will suffice for initial integration.

2.3.2 Data Receipt (Ingest)

Integration of the FEWS product with the AWIPS architecture will require transfer of data (e.g., forecast products) *from the FEWS data cache to the AWIPS persistence entities*. Achieving this will require the addition of an AWIPS II ingest endpoint and plug-in to support this capability.

The current NWS OHD pilot studies do not support the export of data from FEWS or the ingest of data to the IHFS or to archive data repositories; therefore, this would be a new capability.

2.3.3 Data Visualization

The visualization needs of the RFCs are considerably different than those of the WFOs and are supportable by FEWS. The visualization needs of the WFOs are supported by CAVE. These systems should remain separate; only a data exchange will be required for certain WFO functions.

2.3.4 Processing Control

Process control of data receipt, delivery content, and the timing of data transfers between AWIPS II and the FEWS client is essential. The ability to monitor the execution of external applications such as FEWS may also be useful, although it is not required.

2.3.4.1 Data Delivery Control

Interactive or automated control of data delivery to the FEWS client will be required to integrate AWIPS II and FEWS.

CRONTAB control of data delivery would support functionality during the AWIPS II transition. This would not, however, provide the most desirable integration with the AWIPS II SOA. Support for requests and automatic event-based (subscription) data delivery should be provided by the standard AWIPS II services.

2.3.4.2 Data Receipt Control

Interactive or automated control of data delivery to the AWIPS system is desired to control the export of model runs to the AWIPS architecture following execution of hydrological models.

AWIPS II ingest is designed to facilitate extensions for new data types, so the level of effort should be low. Subsequent delivery and use of the data must be considered in the design and will influence the total effort. It is not anticipated that it would not take significant effort to implement interactive or automated control of data delivery to AWIPS.

2.3.4.3 Process Monitoring and Control

FEWS currently allows an adequate degree of control by external applications via a web services interface. Additional utilities used in relation to FEWS (e.g., data extraction from the IHFS database) are controlled by CRONTAB or a command line interface. This will allow a seamless transition with no changes required during initial integration.

Interactive or automated monitoring and control of external application execution via the AWIPS II CAVE architecture may also be desirable. AWIPS II will have process monitoring capabilities in its final form and can be readily extended to support additional process monitoring and control functions as desired. This is not a priority tasking and is not considered to be part of the transition effort.

3.0 Conclusion/Design Recommendations

Based on our collaborative analysis and the plans for the AWIPS II evolution, the Raytheon FEWS Analysis team has concluded that the integration of the CHPS/FEWS and AWIPS II systems should be a relatively low-risk, low-cost effort. The AWIPS infrastructure will provide extensible patterns that can support data delivery to and receipt from the FEWS architecture. Many of the service extensions needed to support data request, subscription, transformation (reformatting), ingest, and GUIs for control will be delivered within the AWIPS II CTR effort. Relatively minor extensions will be required to support FEWS-specific data format and interface requirements.

The Raytheon FEWS Analysis team recommends a phased approach to achieving the long-term goals for FEWS-AWIPS II integration. The current state of the combined system supports the current CHPS/FEWS pilot efforts with the current AWIPS system. AWIPS II deployment should not disrupt these pilot efforts. Phase 1, "AWIPS II Deployment," accomplishes this goal. Phase 2, "FEWS Deployment," will be the replacement of NWSRFS with FEWS. Phase 3, "FEWS Extension," adds functionality to FEWS to further integrate the two systems.

Figure 3.0-1 illustrates the current state of the system supporting the FEWS pilot efforts. An adapter has been implemented to extract data from the IHFS database, format it for FEWS, and write it to a shared directory where FEWS accesses it.
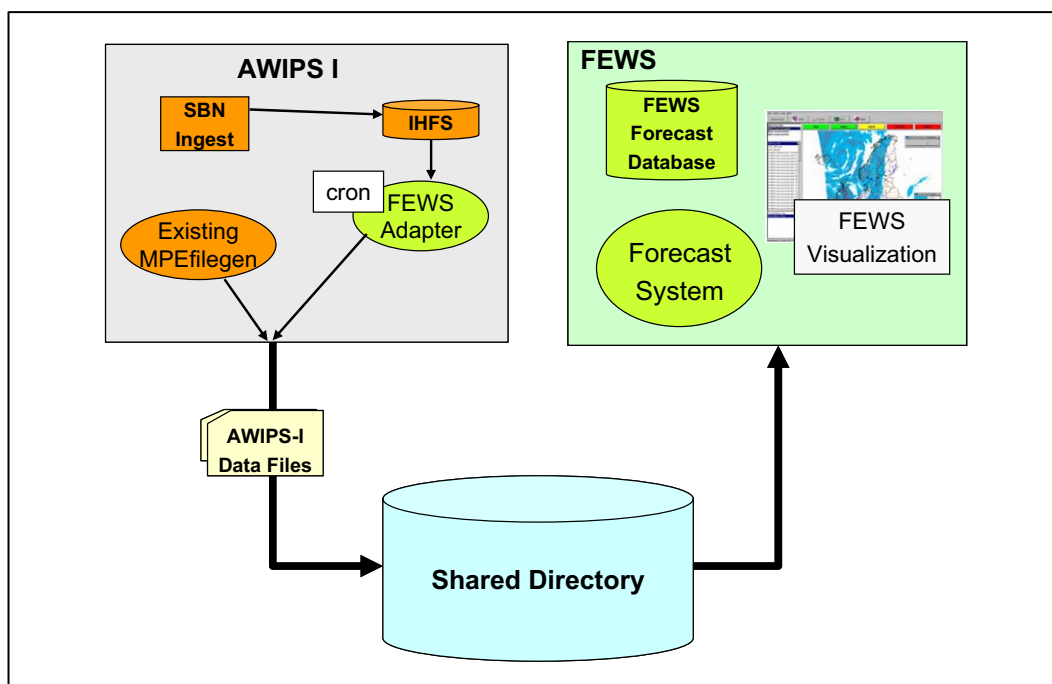

Figure 3.0-1. Current State of System Supporting the FEWS Pilots

Our approach was developed after first considering several options. Each option was reviewed and discussed with experts from Delft, Apex, and NOAA/NWS and evaluated against the following criteria:

- The FEWS-AWIPS II integration must not interfere with the current AWIPS-II schedule.

- Transition from AWIPS to AWIPS II should not disrupt FEWS pilot efforts.
- AWIPS II must supply data in formats needed by FEWS (subscription or demand).
- No AWIPS-II specific changes to FEWS should be required.
- The solution should provide control of data delivery to FEWS (subscription, demand, parameters and areas).
- The solution should minimize design coupling between FEWS and AWIPS II. To the extent possible, data interfaces should be independent of implementation changes.
- The solution should support ingest of FEWS outputs to AWIPS II databases
- The solution should be cost effective across NWS RFC, OHD, and WFO implementations.

Overall, we believe our recommendation provides the best balance across phases in meeting these criteria.

3.1 Phased Approach to Integration

3.1.1 Phase 1: Deploy AWIPS II, Maintain FEWS Pilot

The current CHPS/FEWS pilot studies should be unaffected by the transition from AWIPS I to AWIPS II. This is due to the fact that the IHFS database schema and Multi-sensor Precipitation Estimation (MPE) GRIB1 radar products should remain unaltered by AWIPS II. Although the current use of CRONTAB scheduling and direct access to the AWIPS I data stores will support functionality during transition, it does not provide the most desirable integration with the AWIPS II Service Oriented Architecture. As seen in Figure 3.1-1 AWIPS II simply provides SBN ingest while the rest of the pilot configuration is unchanged.
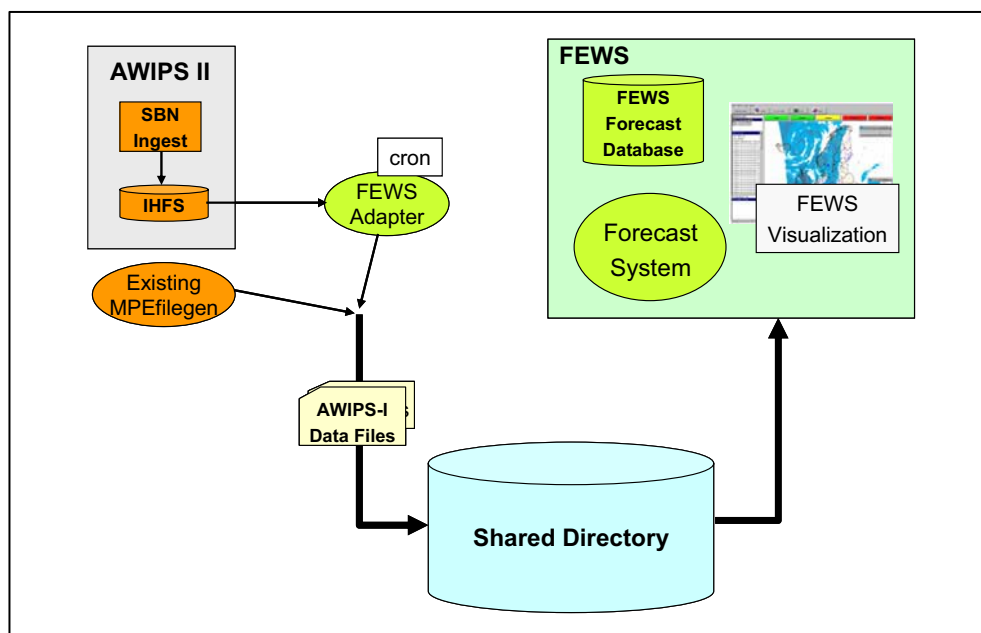

Figure 3.1-1. Phase 1 Solution to Support the AWIPS II: FEWS Data Delivery Interface. *In Phase 1, AWIPS II simply replaces AWIPS I SBN ingest while maintaining existing data access capabilities for FEWS.*

3.1.2 Phase 2: Deploy FEWS (Replace NWSRFS)

Because CAVE displays NWSRFS results in AWIPS II, this phase requires display of FEWS forecast products in CAVE. This, in turn, requires the ingest of FEWS data into the AWIPS II data repositories for access by CAVE. This will require additional tasking (beyond the current AWIPS II migration task orders) to extend the subscription and data transformation services for FEWS-specific input and output data needs. The FEWS-specific effort should be low cost and low risk, with much of the current and planned pilot study work being potentially reusable in the interfaces between FEWS and AWIPS II.

As part of Phase 2, Raytheon recommends extending the AWIPS 1.0 data ingest service to support the anticipated need to accept and store forecast products such as water level and discharge forecasts, forecast reports, and alert messages. Other data related to the forecasting system (FEWS) – e.g., forecast archives and times series of performance indicators – will require permanent storage within the AWIPS II infrastructure.

This phase depends on AWIPS II deployment and execution of additional tasking to extend existing AWIPS II services to support FEWS-specific input and output data needs. The transition from NWSRFS to FEWS would then involve switching over from the NWSRFS-to-CAVE interface to the FEWS-to-CAVE interface. No changes to FEWS would be required.

As new data types or formats are desired by FEWS, new data transform functions, subscription extensions, or AWIPS ingest plug-ins may be required. The AWIPS II architecture is designed to facilitate these types of extensions, so the effort should be limited.

Figure 3.1-2 illustrates the recommended Phase 2 solution for the evolution of the AWIPS II-to-FEWS data integration.
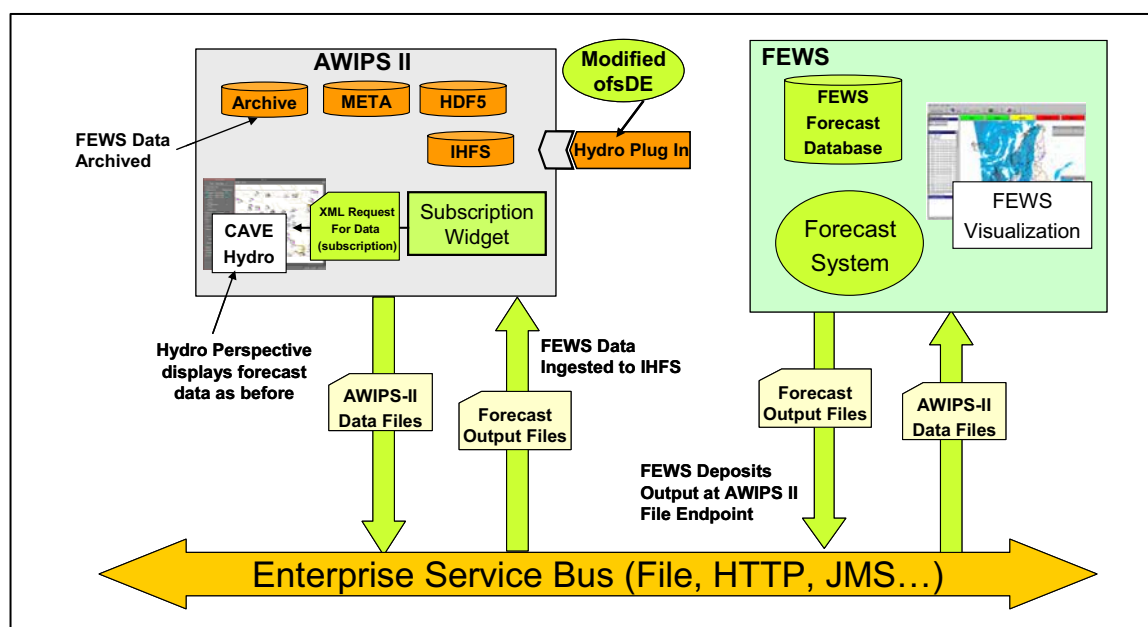

Figure 3.1-2. Phase 2 Solution to Support the AWIPS II – FEWS Data Interface. *Phase 2 extends the ingest and data delivery services specific to FEWS, and displays forecast products in CAVE.*

Note that it may be possible to implement Phase 2 AWIPS II capabilities so that they are included with release 1 of AWIPS II (AWIPS II r1.0). This would provide the means to transition to FEWS at any time after AWIPS II deployment without further releases, which would simplify FEWS deployment logistics while providing flexibility. Should OHD wish to pursue this idea, a pilot effort for Phase 2 will be required to prove out the design. The output of the pilot would be a demonstration, and the associated software would be prototype quality. Production implementation cost and timeline estimates would be provided. At that point a decision could be made whether or not to implement. The implementation could be timed to be closer to anticipated FEWS deployment. It is our understanding that NWS is considering a FEWS operational deployment mid-2009. If this is successful, Phase 2 capability would be required when deploying AWIPS II r 1.0. The Phase 2 capabilities would be dormant in AWIPS II r 1.0 until needed. The pilot noted above could begin as early as June 2008.

3.1.3 Phase 3: Extend FEWS

In Phase 3, FEWS would be extended to provide certain AWIPS II-specific extensions to the FEWS interface; examples include a GUI-based data request/subscription, a SOA base data and message exchange, and support for additional data formats to the FEWS applications. While this phase appears to violate the criteria, "No AWIPS-II specific changes to FEWS should be required," the phase is also not essential to AWIPS II or FEWS deployment, and it is placed after Phase 2. During the pilot efforts slated to take place over the next couple of years, the benefits of extending FEWS can be evaluated. If the benefits do not justify the cost (including long-term maintenance issues), Phase 3 does not need to be executed.

The execution of Phase 3 will require tasking Delft to extend the FEWS system.

Figure 3.1-3 illustrates a possible FEWS extension to enable event-driven data flow to FEWS with FEWS Control.
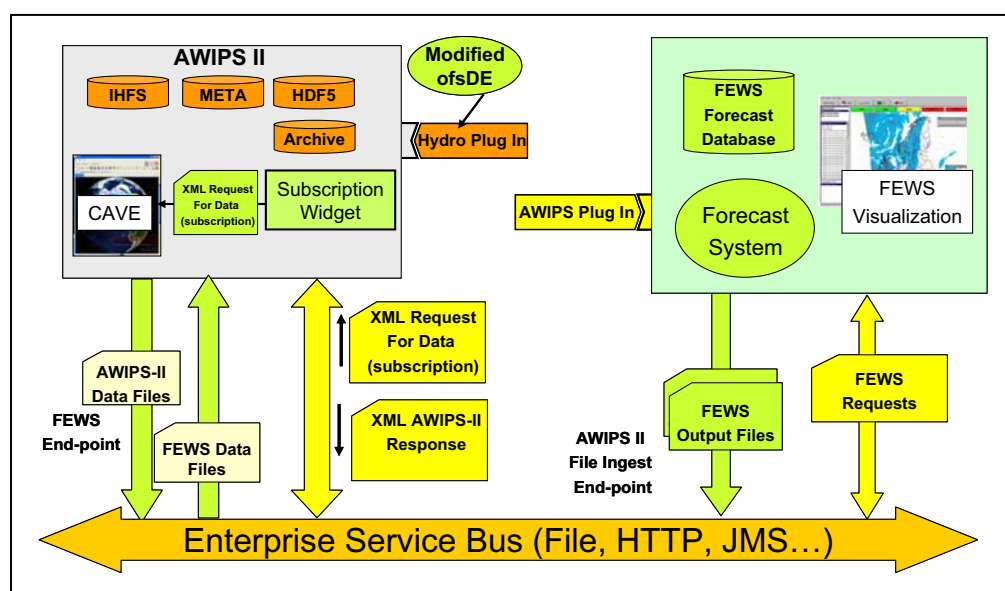

Figure 3.1-3. Phase 3 Solution to Support the AWIPS II – FEWS Data Interface. *Phase 3 adds extension of FEWS to utilize the shared SOA architecture more fully.*

Figure 3.1-4 summarizes our three-phased approach to FEWS-AWIPS II integration.
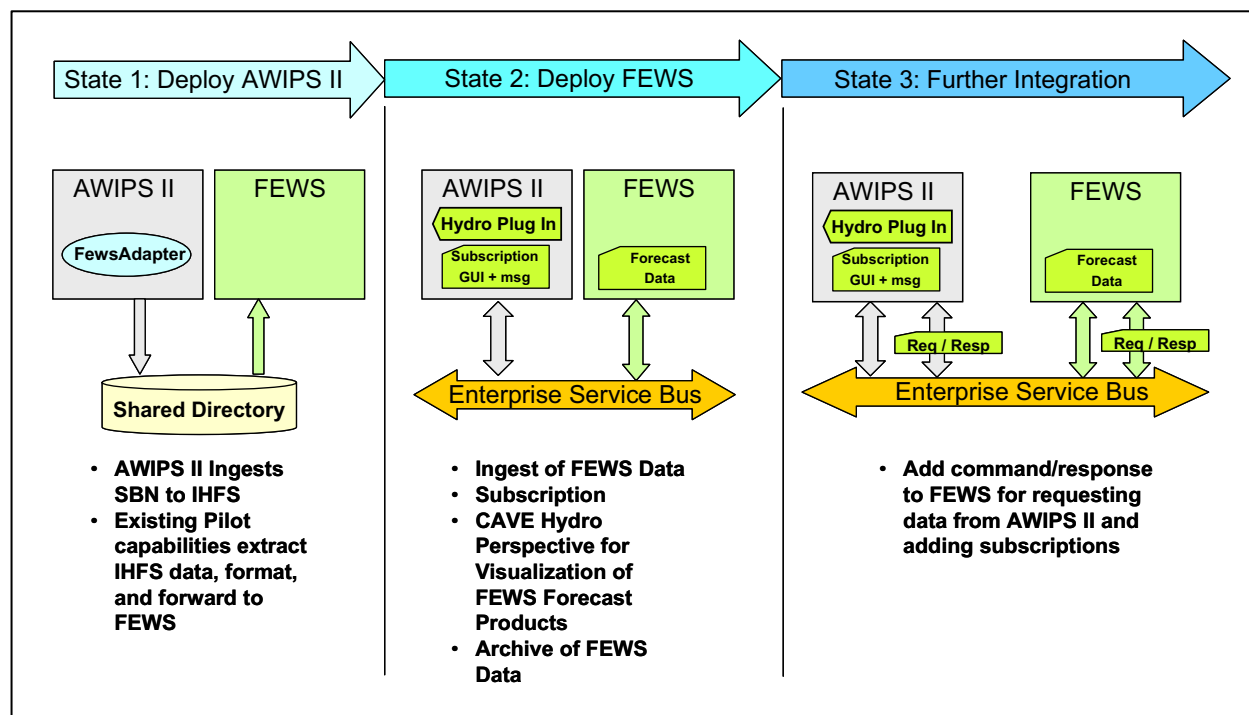

Figure 3.1-4. Summary of Phased Implementation Approach to FEWS-AWIPS II Integration

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