# THE HISTORY OF DAR³E

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## 1. INTRODUCTION

DAR³E, a weather forecasting workstation, is part of a risk reduction effort for modernization of the United States National Weather Service (NWS) field operations. The history of DAR³E begins at the laboratories of the Program for Regional Observing and Forecasting Services (PROFS).

PROFS is now part of the National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory (FSL). As described by MacDonald (1984), it was founded in 1980 with the mandate to improve operational weather services by researching, developing, testing and transferring scientific and technological advances. Within a year, PROFS had begun to develop and test interactive meteorological workstations. In the ensuing decade, PROFS gained considerable expertise by developing over a dozen different workstations.

During this same period, the NWS was developing plans for modernizing and restructuring its field operations. The technological components of this modernization include an advanced Doppler weather radar network (NEXRAD), an automated surface sensing network (ASOS), next generation geostationary orbiting satellite sensors (GOES-NEXT), and a system (AWIPS-90) to process, integrate, display, and support forecaster interaction with these new and existing data sets.

As a result of the need of the NWS to better understand the requirements for AWIPS-90 (Advanced Weather Interactive Processing System for the 1990s) and the growing experience in the advanced workstation area within PROFS, a cooperative agreement was reached between these two NOAA elements in 1984. Through this agreement, PROFS would develop a functional prototype of AWIPS-90 and place it in an operational NWS environment for comprehensive analysis and evaluation. The operational environment was the Denver, Colorado Weather Service Forecast Office (WSFO). The project became known as DAR³E (Denver AWIPS-90 Risk Reduction and Requirements Evaluation).

Experience gained from this and subsequent collaborative risk reduction activities has profoundly influenced both the understanding of requirements and subsequent specifications for AWIPS-90. AWIPS-90 will be developed by private industry beginning as early as next calendar year.

## 2. OVERVIEW

The domain of most of the PROFS workstations has been operational weather forecasting. In this presentation, we will briefly review a few key, early workstations that significantly influenced DAR³E. We will describe how lessons learned from each iteration influenced the characteristics, functional requirements, and design of the each subsequent workstation and ultimately, AWIPS-90. We address issues of data integration, access, animation, presentation and workstation performance. We discuss how these factors forced the evolutionary system-design process for an operational forecasting setting. (An overview of the systems built between 1981 and the present is shown in Appendix A.)

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Data integration was the principal factor which originally drove the design of the early PROFS workstations and continues to affect design decisions today. Integration of the wide variety of data and products to be available to NWS operational forecasters by the mid-1990s has also been one of the primary objectives of the AWIPS-90 effort. Currently, in NWS field offices, several sensing systems have dedicated display devices, requiring the forecaster to shift attention among systems. In addition, each system may present data on different map projections and for different spatial and temporal scales. Mental integration of these multiple data sets is difficult. Such data segregation will no longer be acceptable in the data-rich AWIPS-90 era.

Animation was another of the original design drivers for PROFS workstations. Animation of meteorological data over time is critical to the rapid extraction of information. The default method of viewing products on PROFS' workstations has been to view a time series as a "film loop." When a product is selected for viewing by the forecaster, the most recent instances of that product are loaded into the display memory for immediate animation. To facilitate rapid access to multiple frames, graphics and images are stored in a "display ready" form.

Performance is a critical factor for supporting severe weather forecasting and warning functions. In 1981, the first PROFS workstation could retrieve and display ("load") a single 512x512 pixel image in about 40 seconds. Forecasters using this system unanimously agreed that this was too slow. The 1982 system improved this loading speed by a factor of six. Forecasters still felt the system was too slow. Today's DARE-II system can load images at greater than 10 frames per second (400 times faster than the first PROFS system) and graphics at about 1 frame per second. Yet, one of the most frequent comments about DARE-II is that the system should be faster, especially during severe weather.

Workstation performance has a significant impact on Forecaster Inquiry Time, defined by MacDonald (1985) as the time required by the forecaster to review all of the products necessary to make the correct forecast or warning decision. This becomes increasingly important as the volume of data rises dramatically in the forecast office of the future.

Data access is accomplished via menu selection for all workstations but the very first. The organization of items within menus was driven in part by the goal of data integration. User interfaces were designed to encourage a systematic approach to forecasting with products and functions grouped in a way that is meteorologically logical. For example, products are grouped by geographic scale rather than by type. This organization is based on the empirical observation that forecasters can best comprehend atmospheric phenomena by beginning with the large planetary-scale and progressing to the small mesoscale as described in Bullock et al. (1988) and depicted in Figure 1. To achieve true integration, products grouped in each scale must have similar temporal and spatial resolutions. As subsequent systems grew in functionality and number of products, PROFS endeavored to provide the forecaster with increasingly quick, easy, and utilitarian access to functions and products.

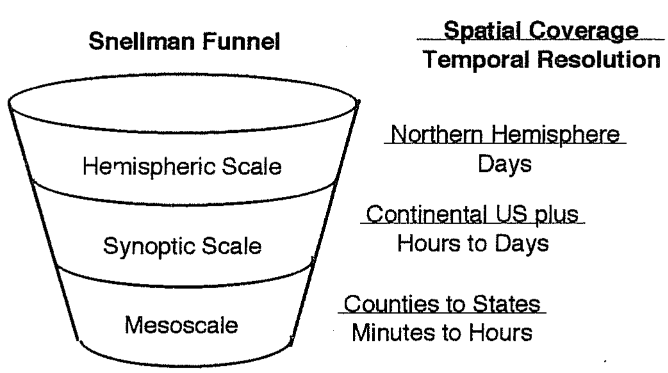


Figure 1. Snellman Funnel approach to weather forecasting.

Data presentation characteristics have been chosen to maximize forecaster understanding of represented atmospheric and weather phenomena in minimal time and with minimal effort. This implies user control over aspects of the data display including choice of graphic overlays on images, image combinations, color table selection, map background selection, zoom, pan, and animation.

## 3. HISTORY

The PROFS system design methodology is to iteratively build systems to test the efficacy of combinations of data sets for making mesoscale forecasts. The results of evaluating these systems then serve as useful input to the designers of next-generation weather-forecasting systems. In this brief history we emphasize issues raised in the overview as they pertain to the systems named POWS (1981), POWS82, POWS83, RT85, DAR$^3$E (1986), and DARE-II (1989).

### 3.1 POWS – 1981

POWS is the original PROFS Operational Workstation. During the first year of PROFS, funding emphasis was placed on development of the Exploratory Development Facility, a networked computer system for data ingest and generation of display-ready products. This facility has grown over the years and is described by Brown (1983), Grote (1985), and Mandics (1986). It will not be further discussed here.

As described by Beran and MacDonald (1981), the emphasis for the 1981 system was on determining which combinations of products are most useful for mesoscale forecasting. Given computer-hardware costs and the need for real-time access to data, designers recognized that POWS should focus on providing diagnostic and simple prognostic information rather than locally-generated model output. Although we are approaching the ability to provide local-model output, this focus is still the case today.

After a review of existing interactive systems in research environments, PROFS developers recognized that an operational environment required a tailored, direct approach to product selection. The initial command-line oriented interface emphasized direct selection of the few available products, with no hierarchical organization superimposed.

Details of POWS and POWS82 are presented by Reynolds (1983). During development of POWS, it was recognized that satellite images required re-mapping to minimize navigation and viewing-angle errors. Formal evaluation and informal feedback showed that increased temporal resolution is required for mesoscale convective forecasting and that data assimilation and objective techniques required improvement.

As described by Leserman (1991), weather forecasting imposes a high cognitive load. Under stringent time constraints, the forecaster must 1) access, view, and assimilate data from a variety of sources and in an assortment of forms; 2) formulate hypotheses for the progression of atmospheric conditions; and 3) compose and issue a spectrum of forecasts. A major insight, resulting from evaluation of the original POWS and reflected in the design of all subsequent systems, was the importance of system ease-of-learning and ease-of-use to mitigate this cognitive load.

### 3.2 POWS82 – 1982

Intended to address the ease-of-learning and ease-of-use issues, the major modification in the 1982 system was the introduction of a menu to replace the command-line user-interface. This menu, displayed on a color graphics terminal, was populated with "buttons" that could be selected with a light pen. The buttons were grouped into fixed regions of the menu called panes. (A schematic of pane organization is shown in Figure 2.) Selection of a button with the light pen would invoke the presentation of a particular product, control some aspect of the display such as animation speed, or cause the contents of another pane to be modified.

POWS82 introduced hierarchical organization of products based upon the Snellman Funnel approach, depicted in Figure 1. One pane was dedicated to product selection and contained all the product-selection buttons for a single meteorological scale. Another pane contained buttons for selection of one of the four POWS82 scales. These scale-buttons were used to control the contents of the product-selection pane. Yet another pane contained animation control buttons for speed, first frame dwell, and so on. In POWS82 the product selection pane doubled as a region to display text products. This was very inconvenient and in POWS83 an additional screen was added to the workstation for text product display.

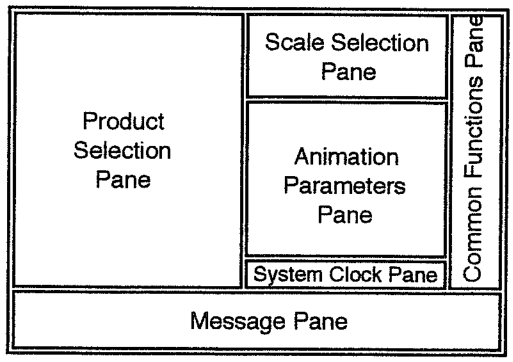


Figure 2. Schematic of menu pane organization for early workstations.

The POWS82 menu simplified data access and the control of data presentation. The organization of buttons on the menu superimposed structure on the forecast process by making it easy to step through meteorological scales. Difficulties were related to poor performance of the light-pen, slow system response, and lack of feedback. For example, once the user selected a product button, it would take several seconds to begin to load that product to the display. In the interim, the user would wonder whether a valid light-pen "hit" had occurred and might re-select the button, thereby re-initiating the load process.

### 3.3 POWS83 – 1983

It was recognized that less-than-superlative performance would continue to be the norm because of hardware availability and costs, the large size of image products, and processing requirements. Therefore, in 1983 a special-purpose User Interface Management System (UIMS) was developed to address feedback requirements and other human factors issues. As described by Leserman (1991), this UIMS would serve as the platform for the user-interface for POWS83 and subsequent systems including RT85 and the first DAR$^3$E workstation. Using the UIMS, menus for subsequent systems would be specified using a graphical editor for creation and location of menu panes and buttons. Some workstations were built using the UIMS editor only - not a new line of code was written.

All user-feedback was handled within the UIMS software component. For example, when a product-selection button was selected, it would immediately change color and shape, informing the user that a valid hit had occurred. Then, during the process of loading the product from mass storage to display memory, the product-selection button would flash. When the load was complete, the button would stop flashing but retain the shape and color associated with selection. As reported by Schlatter et al. (1985), most forecasters became comfortable with this new user-interface within an hour.

In POWS83, the somewhat unreliable light pen was abandoned in favor of a touch screen. The touch screen was more reliable, but not sufficiently so. Also, forecasters working normal shifts found use of the touch screen to be physically fatiguing.

A well-received addition in POWS83 was the "green" time that appeared next to each product selection button. Each such four character time-string is automatically updated to display the observation time of the most recent instance of a product to arrive in the database. Green times serve as a highly visible product notification and inventory mechanism and are still in use in current workstations.

The hierarchy imposed on menu item organization (beginning in 1982) allowed buttons for many products and functions to be available within limited screen space. As the number of products, functions, and applications increased in subsequent systems, the hierarchy got deeper. As this happened, specific buttons became harder for the user to locate. Therefore, menus starting with POWS83 were organized to minimize the depth of the hierarchy. The POWS83 touch-screen interface to the menus imposed a limit on the minimum button size. In later workstations a mouse replaced the touch screen, allowing a smaller button target. Thus, more buttons could fit on the screen and a shallow hierarchy was preserved, even with an increasing number of buttons.

Sluggish workstation response was still a problem in POWS83. Improvements were needed in the speed of image and graphic product loading and in the redraw rate for menu panes.

### 3.4 RT85 – 1985

The RT85 system introduced two major changes from previous systems. First, the touch screen was replaced with a mouse for the selection of products and functions. Also, a second meteorological product display was added to the workstation. Both changes had profound affect on workstation use and both remain through the current DARE-II realization.

Mouse. The use of the mouse as the menu selection device was immediately accepted by all users as a significant improvement over all previous selection methods. It was easy to master and not tiring to use. More importantly, it accommodated more buttons per menu-hierarchy level as described above. This was important because of a growing product set and the addition of duplicate controls for the second meteorological display.

Display controls. Unfortunately, the duplication of display controls within a single menu created confusion for the user of the workstation. Because the product-selection buttons were not also duplicated, the user needed to first select a button indicating the destination display of the next product selection. Pre-selection of the display-destination button was frequently omitted because the user's attention was focused on the forecasting task, not on control of the workstation. The irritating result was that products were often unintentionally loaded to the wrong display, possibly forcing unintended erasure of previously loaded products.

For example, a forecaster might load an 8-frame satellite-image loop with three graphic overlays on display number one. He might then adjust the display controls by modifying the image color table, changing the color of overlays, setting the loop rate, zooming in for detail, and so on. The forecaster might then decide to compare this data with, for example, the latest Doppler radar reflectivity image loop on display number two. We observed that the typical forecaster selection sequence was as follows: decide which product to look at next, locate its button on the menu, and select it. Since, in this sequence, the display-destination was not explicitly changed, the Doppler product selection would replace the carefully adjusted contents of display number one.

This problem created a high level of user frustration and, surprisingly, it did not diminish substantially with user experience. Furthermore, the problem was exacerbated in heat-of-battle situations, when it could be least afforded. The problem was so acute that it became a design driver for subsequent systems. It was reduced in DAR$^3$E by changing the "load order," that is, product-button selection did not directly load the product as in previous workstations. Rather, after product selection the forecaster was required to explicitly select the appropriate display and that subsequent action caused all selected products to be loaded. Although this revised procedure reduced user frustration, it increased the number of step in the load process. Elimination of this new problem became a design driver for DARE-II.

## 3.5 DAR$^3$E – 1986-1989

The design of the first DAR$^3$E system was based on the RT85 system. However, the purpose and objectives of DAR$^3$E were significantly different from any previous PROFS workstation. The purpose was to develop a prototypical AWIPS-90 workstation based on a set of functional requirements developed by the NWS. The primary objectives were 1) to fully support the public forecast function at the Denver, Colorado WSFO (Weather Service Forecast Office) and 2) to provide insight into AWIPS-90 design and performance requirements along with associated NWS modernization transition issues. Installed in the Denver WSFO in the fall of 1986, DAR$^3$E physically replaced the existing, operational, "AFOS" console which supported the public forecast function. DAR$^3$E then supported that function for three years.

DAR$^3$E introduced into an operational environment for the first time, many of the advanced data sets planned for the modernized NWS. This included a suite of radar products from NCAR's 10-cm CP-2 Doppler. The CP-2 data were processed to simulate a subset of products that would eventually be provided to NWS offices by NEXRAD.

Deployment in an operational setting demanded more stringent requirements for system reliability and functionality. Data sets had to be produced continuously to support around-the-clock operations. DAR$^3$E was not a summertime, daytime operation as were most previous PROFS exercises which had focused exclusively on short-range (0-12 hour) forecasts and warnings for a limited area (Eastern Colorado). The Denver WSFO has a much longer period and larger area of forecast and warning responsibility. All data and functions required to support this responsibility, but which were not in RT85, were added to this system. Three new product scales and hundreds of new products were added, including a full suite of operational text and graphic products. A new text workstation was developed to complement the graphic/image workstation. Although a significant enhancement, this new text workstation will not be discussed here.

Data access. Graphic products will play an increasingly important role in modern forecasting. The number of graphics available on DAR$^3$E increased by an order of magnitude over RT85, to more than 400. By the AWIPS-90 era this number will increase by more than another order of magnitude. Existing methods of graphic product selection were not adequate to allow the user to view a fraction of the available graphics in the time allowed for the forecast formulation process. More effective data access and display methods were needed. DAR$^3$E introduced the first effort to improve access to graphics through a concept called "family graphics."

A graphics family is a group of related graphic fields combined for easy access and presentation. For example, one family might contain several fields from a single numerical model. Families were implemented as an 8-frame animation-loop of 8-bit images with each field embedded as a single bit plane. Thus, up to 64 individual graphic fields (including the map background) could be rapidly loaded with a single button selection. An easy means to independently toggle the visibility of each field allowed the forecaster to view, in animation, any combination of the fields which made up that family. Several families of graphics were automatically generated with DAR$^3$E, including single-model and model-comparison families. Heideman et al. (1989) report that this new method of data access proved to be one of the most popular features of the DAR$^3$E system, especially during non-convective periods.

Display controls. For improved workstation interaction, DAR$^3$E introduced a specially designed keypad-and-trackball input-device called a "trackpad." Each graphic/image display had a dedicated trackpad. This was considered a significant improvement over previous interactive methods because it allowed the forecaster to control the data display (e.g., zoom, toggle overlays, and step through frames) without removing eyes or attention from the display. A victim of its own success, the trackpad suffered wear from very heavy use and was soon replaced by a strengthened version.

Data presentation tradeoffs. Animation was enhanced in DAR$^3$E by providing loops of up to 32 frames in length on each display. However, in order to achieve this new capability, we faced an interesting data-presentation dilemma. This involved tradeoffs of loop length, workstation performance, and data resolution. Understanding this dilemma requires a brief description of the hardware used and our allocation scheme for display hardware resources.

The two graphic/image displays of DAR$^3$E were controlled by a single graphics device, with display memory organized as 32 bit planes of 1024 by 1024 pixels. Each graphics/image display was assigned 16 of these 32 planes. This memory resource was automatically allocated, but depended on the loop length and product requests of the user. For example, if the selected loop length for a display was 4 frames, then, each frame being 512 by 512 pixels and each pixel being 8 bits "deep," 8 bit planes of that display would be allocated to each of the 4 frames. Four more bit planes for that display would be reserved for the map background and up to three one-bit-deep graphical overlays. The last 4 planes were not used in 4-frame mode.

Table 1 shows how bit planes were allocated for loops of 4, 8, 16, and 32 frames. For 8 and 32 frame loops, addition of the map background and graphic overlays degraded the image in the number of bits available per pixel. This is equivalent to a reduction in the depicted precision of the data value for each pixel. For 16 and 32 frame loops, the spatial resolution was also reduced, from 512x512 to 256x256, quadrupling the areal coverage of each pixel. Thus, resolution of images in 32 frame loops was degraded in both spatial and precision dimensions. An 8 or 32 frame image loop with three overlays resulted in severely degraded imagery. The tradeoff resulted in inconsistent presentation of products – a situation we were trying to avoid.

| Bit plane | 4 frame loop | 8 frame loop | 16 frame loop | 32 frame loop |
|---|---|---|---|---|
| 1 | 512x512 image | 512x512 image | 256x256 image | 256x256 image |
| 2 | " | " | " | " |
| 3 | " | " | " | " |
| 4 | " | " | " | " |
| 5 | " | degrading overlay 3 | " | degrading overlay 3 |
| 6 | " | degrading overlay 2 | " | degrading overlay 2 |
| 7 | " | degrading overlay 1 | " | degrading overlay 1 |
| 8 | " | degrading map background | " | degrading map background |
| 9 | graphic overlay 3 | 512x512 image | graphic overlay 3 | 256x256 image |
| 10 | graphic overlay 2 | " | graphic overlay 2 | " |
| 11 | graphic overlay 1 | " | graphic overlay 1 | " |
| 12 | map background | " | map background | " |
| 13 | unused | degrading overlay 3 | unused | degrading overlay 3 |
| 14 | " | degrading overlay 2 | " | degrading overlay 2 |
| 15 | " | degrading overlay 1 | " | degrading overlay 1 |
| 16 | " | degrading map background | " | degrading map background |

Table 1. Allocation of display memory for RT85.

In addition to product resolution degradation, frame loading speeds had not been increased from previous systems. It could take over two minutes to simply load a 32 frame loop, a very high cost for operational forecasting. Despite the degradation problem, the most frequently selected loop length was 8 frames because it could be loaded relatively quickly (in about 30 seconds) and because it retained the full 512x512 spatial resolution. Loop lengths greater than 8 frames were infrequently used. Thirty-two frame loops with overlays were almost never used. This design tradeoff of display memory resources became an issue again with DARE-II.

### 3.6 DARE-II – 1989-present

DAR$^3$E was replaced at the Denver WSFO in the fall of 1989 by the next generation system, DARE-II. The DARE-II development represented a dramatic departure from the previous PROFS workstation iterations. First, it involved a complete redesign and re-implementation, dropping the User Interface Management System (UIMS) software developed with POWS83. It incorporated a new hardware platform, independence of the two image/graphic displays, and a new user interface with menus overlaying each image/graphic display. Second, DARE-II was not just a new workstation, but a complete meteorological system with multiple workstations, data ingest and data storage subsystems, and distributed processing on its own independent local area network (LAN).

DARE-II was built for continued support to the NWS modernization risk reduction activities. The primary purpose was to move the Denver WSFO closer to an AWIPS-equipped office to allow the NWS to better understand and prepare for operational and transitional issues associated with modernization. When installed in the Denver WSFO, it completely replaced the original DAR$^3$E, as well as all other consoles supporting office functions.

Performance. Performance of the original DAR$^3$E workstation at Denver was minimally acceptable, especially during severe weather. Therefore, as described by Bullock and Walts (1991), performance considerations drove many of the design decisions for DARE-II. To enhance performance, each DARE-II workstation has a dedicated host processor, and each image/graphic display has a dedicated display processor. This provided true workstation and screen independence which was also a critical factor for reliability.

In addition, each animation workstation has a local, dedicated, high-performance image disk on which all (several thousand) current satellite and radar images are stored. Image frames of 512x512 resolution can be retrieved from this local disk at a rate of up to 30 images per second. Benefits of this architecture are speed and reduction of traffic on the LAN. Additionally, it allows for "graceful degradation" since the only penalty for a complete failure of an image disk is in performance, not functionality. Thus, the distributed nature of the DARE-II architecture, with redundant processors for each critical function, ensures both high reliability and performance during critical weather situations.

Data access. As a result of the product-selection problems described above and because of the large increase in the number of products with (over 10,000 total), the DARE-II user interface was completely redesigned. The most apparent change is that menus are no longer on a dedicated display, but are fully integrated as an overlay on each meteorological display. The visibility of the menu overlay may be toggled with a press of a mouse-button. This presentation of menus simplifies the product-selection process and clarifies feedback regarding the display state.

The new menu system is displayed within moveable, overlapping windows, not the fixed panes of previous systems. Thus, although the new menus maintain the hierarchical approach, the user is free to "tear-away" components from the location of original display. Components that are so "torn" and relocated, remain on the screen, even when higher levels of the hierarchy are removed. This allows the forecaster to tailor the menus for personal preference or a particular forecasting scenario such that there is always direct access to frequently requested products. It also allows forecasters to monitor the receipt of products of interest via the product arrival ("green") times that are displayed within each product button and updated dynamically upon receipt of a new version. In severe weather situations, forecasters can watch for receipt of a critical product and then, with a single mouse click, load that product into the display in seconds.

Another important data access feature of DARE-II involves the concept of "bundles." The state of a graphics/image display at any time is called a bundle. It includes loaded products and their attributes (e.g., loop length and color table). A dynamic "recall list" stores the last 10 bundles for each display. Any bundle from that list may be re-displayed with a single button selection. Static bundle lists (called procedures) may be constructed by the forecaster for recall at any time. As the forecaster steps through one of these procedure lists, the most recent products for each bundle will be loaded to the display. Procedures may be constructed for a variety of weather events, seasons, or personal preferences.

The DARE-II user interface also includes an improved matrix-menu for selection of display-ready graphic products and generation of graphics for gridded fields. This matrix menu is user-tailorable, allowing selection of models, levels, and fields. Within the tailored menu, shortcuts are provided for loading comparative animation sequences.

## 4. SUMMARY AND CONCLUSIONS

Interactive, real-time, meteorological workstations have come a long way during the last decade – from workstations with very limited functions, limited data sets, and cumbersome user interfaces to the modern workstations of today. The keys to modern workstation design include full integration of data sets, a functionally efficient user interface, high system reliability, and overall system performance (speed, speed, and more speed).

Through the iterative process from POWS82 to DARE-II, PROFS has worked very closely with the operational meteorological community. Feedback from operational forecasters performing real forecasting and warning tasks in real time provided the basis for changes to each subsequent system.

Many of the lessons learned during this process have been incorporated into the specifications for the AWIPS-90 systems which will be developed by private industry for the NWS.

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| **System,**<br>Season of First Use,<br>*# of Products* | Primary Use(s) and Evaluation Techniques |
|---|---|
| **POWS**<br>Fall 1981<br>*~ 15 products* | Controlled exercise using canned data sets made available in simulated real time. Informal feedback from test subjects. |
| **POWS82**<br>Summer 1983<br>*~ 25 products* | Re-implementation of POWS with improved user interface. |
| **POWS83**<br>Summer 1983<br>*~ 100 products* | Three month, real-time, summer-season, controlled exercise conducted by research and professional forecasters to evaluate system and data for convective weather. |
| **MERIT**<br>Fall 1983<br>*~ 1,000 products* | Evaluation of techniques for least fuel-consumption routing of aircraft considering the weather and atmospheric scenarios. |
| **Hi-Res Radar Test**<br>Winter 1983-84<br>*~ 8 products* | Evaluation of the efficacy of high resolution radar data sets. |
| **Cool Season Test**<br>Winter 1983-84<br>*~ 100 products* | Controlled exercise to test the efficacy of data sets oriented to winter weather scenarios. |
| **ARTCC System**<br>Summer 1984<br>*~ 100 products* | Two year operational evaluation by the staff meteorologist at the Denver Federal Aviation Administration (FAA) Air Route Traffic Control Center (ARTCC). |
| **RT85**<br>Summer 1985<br>*~ 400 products* | Second, more extensive, three month, real-time, controlled, summer-season exercise. |
| **DAR$^3$E**<br>Fall 1986<br>*~ 2,000 products* | Three year operational validation by the Public Forecaster in the Denver National Weather Service (NWS) Forecast Office to evaluate the system as part of a risk reduction effort for next generation NWS forecast office technology. |
| **POWER**<br>Spring 1987<br>*~ 400 products* | 1) Intended as an affordable system for research meteorologists. 2) Spring-season exercise at the National Severe Storms Laboratory in Norman, OK. |
| **SERS**<br>Summer 1987<br>*~ 400 products* | 1) National Center for Atmospheric Research test at Stapleton International Airport for wind-shear detection. 2) Installed for teaching at Colorado State University. 3) Rotated through National Weather Service offices for training. |
| **Joint Ice Center**<br>Summer 1989<br>*~ 200 products* | Operational use by Ice Analysts at the Navy/NOAA Joint Ice Center. Hardcopy output faxed to ships. |
| **DARE-II**<br>Fall 1989<br>*~ 10,000 products* | Functional prototype of AWIPS-90 system supporting all functions in the Denver, Colorado Weather Service Forecast Office (WSFO). In January 1991, a second DARE-II system was installed in the Norman, Oklahoma WSFO to validate infrastructure to support a modernized NWS. |
| **PC System**<br>1990<br>*~ 2000 products* | Low-cost implementation of operational meteorological workstation with much of the functionality of DARE-II. |

Appendix A. PROFS/FSL meteorological workstations.