Chapter 4

Technology Infrastructure

A forecast center with a flash flood forecasting program must be able to process and analyze *in situ* (rain gauge and stream gauge) and remotely sensed (radar and satellite) data to detect the occurrence of a flash flood and forecast its impact. A forecast center requires a variety of hardware, software (including computer applications and programs), and communication capabilities to support and maintain this flash flood detection and prediction capacity. Maintenance programs and backup capacity are also needed at a center.

What Is in This Chapter?

This chapter should be read by persons who need a basic understanding of the types of hardware and software (both operating systems and applications programs), maintenance programs, and backup plans that are necessary for a warning plan to function.

The chapter contains sections that discuss the following topics:

- **Operating systems and hardware** (workstations) available for use at a forecast center
- **Application programs** needed to collect, analyze, integrate, display data and disseminate products at a center
- **Redundancy programs** and their importance
- **Maintenance program requirements** for a forecast center

Operating System and Hardware Requirements for Flash Flood Prediction and Warning

A forecast center requires computers and computer operating systems to effectively collect, process, monitor, and display earth observation data and to produce and disseminate products. Currently there are two main choices for hardware and operating systems: PCs with Windows or Mac OS X and UNIX-based workstations. Each has its strengths and weaknesses, so the choice is sometimes based on personal preference or the system with which an organization has had more experience. Each requires significant maintenance, redundancy, and attention to security to ensure data availability and processing capability at all times.

Tip

A NMHS should make sure that firewalls and other security measures are in place to protect the integrity of their networks.

Under optimal conditions, all forecast centers within an NMHS would use the same hardware, operating systems, and applications. That way development, maintenance, trouble shooting, and operations could be standardized, which saves money. The reality is the operating system and hardware chosen by a center is often dictated by institutional norms, staff skills and capabilities, and/or budget constraints or cycles.

The number of workstations needed for center operations depends on the hardware and operating system, the number of applications, the extent of communications, and the approach taken to ensure the redundancy of critical functions.

Important Points to Remember about Operating Systems and Hardware

- There are pros and cons to consider in using either PCs with a Windows or Mac operating system or a UNIX/Linux-based system in a forecast center environment.
- All systems require redundancy and security measures to ensure uninterrupted operations.
- Using the same hardware, operating systems, and applications within all forecast centers reduces the costs of development, maintenance, trouble shooting, and operations.

Computer Applications for Flash Flood Forecast Support

Computer application programs are critical to forecaster success at maintaining situational awareness. Applications can also provide processed information from raw earth observations for input to decisions on what products the forecast center needs to issue. The requirements for rapid characterization and determination of threats include processing speed, sufficient observation network density, and sufficiently short interrogation intervals of each sensor in the network.

Applications

Applications are groups of computer code that provide a center's forecaster with tools needed to maintain situational awareness, collaborate with other centers, make decisions, prepare products, and disseminate these products in a timely fashion. In other words, applications help the forecaster do the required job, and most of these applications are critical to getting the job done. Experience at established forecast centers suggests that flash flood forecast support application functions can be divided into several categories:

- **Collecting** earth observation data in real time, especially rainfall and streamflow data

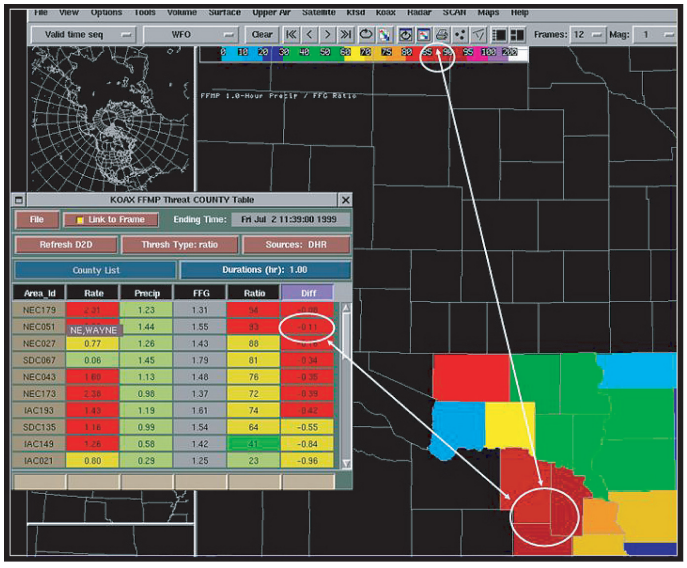
Tip

The center's operating system usually dictates what form the applications take, for example, Tool Command Language/Tool Kit (Tcl/Tk) for UNIX-based systems and C++ for Windows-based systems.

- **Processing** and storing data in real time
- **Monitoring** data for exceedance of threshold criteria
- **Computing** parameters that must be derived from observed data
- **Displaying** data and derived information for the forecaster to maintain situational awareness
- **Creating and Disseminating** text and graphic products to customers and other forecast centers

Each center may utilize applications developed elsewhere or develop their own on-site if such staff capability exists and customization is desired. The following are some functions that require computer applications to support a flash flood warning program. The list is by no means exhaustive.

- Collecting, decoding, and digitally storing earth data observations
- Managing relational database of observations and metadata
- Checking incoming observational data for quality and flagging or rejecting suspect readings
- Displaying data
  - Numerical tabulations of gauge reports
  - Graphical displays of gauge reports
  - Mapped displays of gauge reports
- Comparing precipitation estimates to Flash Flood Guidance (FFG) (see Chapter 5) and alerting forecaster when guidance is exceeded as illustrated in the example in Figure 4.1
- Comparing precipitation estimates to Flash Flood Potential Index (FFPI) or other programs that modify FFG (see Chapter 5) and alerting forecaster
- Computing rate of change at gauges, extrapolating future values, and alerting the forecaster when FFG levels are exceeded
- Routing rainfall downstream and comparing to flood stage, etc.



NOAA/NWS

Figure 4.1 Example of an AWIPS FFMP product

- Mapping and displaying radar reflectivity data in real time and alerting the forecaster when reflectivity thresholds are exceeded
- Displaying radar-observed incremental storm total precipitation data and alerting the forecaster to potential problem areas
- Comparing radar reflectivity data through ZR relationships, for instance, the relationship between radar reflectivity and rain rate in a power law form, and relating to FFG and/or FFPI
- Generating text and graphical summaries of observed data, routine forecasts, and warning products
- Disseminating products to appropriate communications channels.

Important Points to Remember about Computer Applications and Processing Requirements

- A forecast center with flash flood forecasting responsibility requires computer software applications to maintain situational awareness, make decisions, and produce and disseminate flash flood products.
- A forecast center can borrow applications developed by other centers or develop their own specific software.

Redundancy and Backup Capabilities

As briefly discussed in the section on backup communications in Chapter 3, several types of backup systems should be used by forecast centers. Alternate communication paths for data collection and also for product dissemination are needed by each center in the event of the failure of one of a center's primary communication links. Similarly, centers should not rely on a single network or single gauges, but utilize redundant networks. Then if their primary earth data network is unavailable, either through equipment failure or communications problems, the center can still function using alternate networks.

Center **functionality** backup by another center means that procedures are in place for a provincial or local forecast center (and ideally an NMHS) to assume the functions of one of its neighboring forecast centers if the latter has lost all communications links. Typically, a center should have connections to at least two other centers, and each forecast center should have agreements with at least one other center to provide backup communications.

Tip

Avoid the need to invoke full backup by creating redundant

- Communications
- Hardware, and
- Software systems

Full backup capability by another center theoretically provides complete redundancy of the original center's functions. There is, however, a high price for such a capability. The backup center must be trained in the other office's procedures and responsibilities, and additional communications channels are usually needed if the backup center is to collect all pertinent data and reach all of the original center's customers. And of course, the backup site staff must test backup procedures frequently.

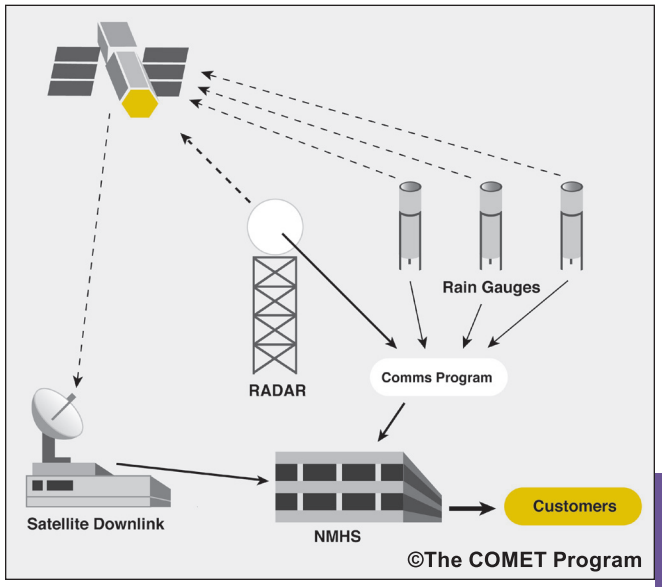


Figure 4.2 Example of redundant data communications pathways

Because of the high cost in both funds and resources and the high probability of encountering problems due to the infrequency of use, full backup should be used only as a last resort. A center should strive to establish on-site redundancies in communications, hardware, and software so that it can continue to function in the event of a minor system outage. Hardware redundancy is an important requirement for a center. This hardware redundancy goes hand in hand with the need for a center to obtain redundant rainfall and stream flow data from several different networks via several different communications channels whenever feasible. Redundancy helps to ensure that the data for applications programs will be available when most needed: during an event. As an added bonus, the backup system can also be configured as a training tool.

Backup Power

When and where possible a forecast center should provide backup power for critical observation platforms, communications hardware, and processing computers. For remote gauges backup power often can be provided by solar-charged batteries. For major installations like radar sites and forecast center computers a sizable diesel backup power generator is necessary. This can be a large investment, but invaluable when the primary power is lost due to storms or other causes. A center should have enough generator fuel on hand for at least three days of operation. The system, including an accompanying uninterruptible power supply, should be tested periodically to ensure smooth cutover in the event of a loss of primary power.

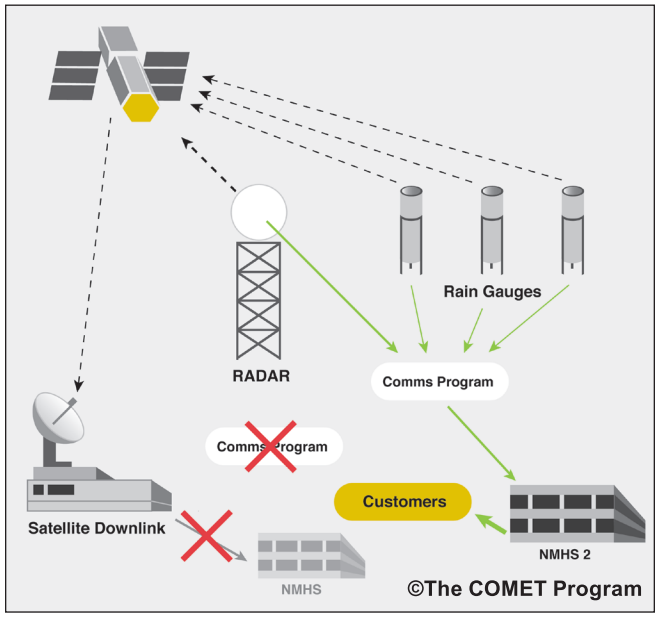


Figure 4.3 Example of full functionality backup by another NMHS

Important Points to Remember about Redundancy and Backup Operations

- Full backup capability by another center theoretically provides complete redundancy of the original center's functions, but the cost is high.
- Because of the high cost and high probability of encountering problems due to the infrequency of use, full backup should be used as a last resort, and each center should strive to establish on-site redundancies in communications, hardware, and software.

Maintenance Requirements

A well-coordinated and supported maintenance program is critical to the success of a forecast center. The breadth and depth of the maintenance program requirements will depend on the types of equipment deployed by that center and the extent to which the center maintains the equipment in-house. For example, if a center needs to deploy its own streamflow or precipitation gauges, then the training and skill set of the center's electronics technicians will be different than those for a center that relies solely on international gauge networks or one whose networks are maintained by another government agency or contractor. Similar conditions exist for computer and communications hardware and software.

There are strong arguments favoring use of an in-house maintenance program versus relying on other groups to maintain critical equipment. These include:

- Greater control over technician availability, especially after normal work hours
- Greater control over technician training
- Creates career ladder for technicians
- Constant exposure to warning center operations creates a better understanding of the importance of responding quickly, especially during major flood events

There are also good arguments, especially with regard to budgets and redundancy of effort, for relying on private contractors or technicians from other government agencies for the maintenance of the center's critical equipment. These include:

- Agency training program costs, including initial and refresher courses
- Overhead for full-time personnel
- Avoidance of underutilization of technicians at centers with smaller workloads

Whether a center operates with an in-house maintenance program, contracts out all maintenance, or has a program that is a mixture of the two approaches, it must track all maintenance activities in order to effectively manage the program. A center should establish an Engineering and Maintenance Reporting System (EMRS) similar to those used by many forecast centers.

The data collected by EMRS are vital to achieving maximum responsiveness to the center's mission. EMRS should be the primary field-level-maintenance tool for data collection, analysis, and maintenance-workflow management. EMRS data allow the center to:

- Determine system reliability and maintainability (R&M)
- Anticipate system and facility maintenance requirements
- Measure the effectiveness of system and facility upgrades and modifications
- Provide configuration data for specific systems and facilities
- Provide evidence of a system's operational status for use in legal matters
- Monitor engineering resources expended on designated systems and facilities
- Provide program performance data
- Manage maintenance workflow at the center
- Assess system and facility maintenance requirements, and assist in planning for future staffing levels

A center should establish what constitutes reportable maintenance events. These are events that should be tracked in order to maintain the center's programs. In general, there are five types of reportable maintenance events:

- **Corrective Maintenance** – The remedial actions required to correct failures and restore system/equipment or facility operation to prescribed capabilities and tolerances. This includes unplanned and non-periodic repairs, as well as system hardware or software maintenance performed as a result of evidence indicating a failure has occurred or is imminent.
- **Equipment Management** – The accomplishment of system, equipment, or facility activation, deactivation, relocation, and other similar activity.
- **Modification** – The authorized hardware and/or software configuration changes required to improve or extend system, equipment, or facility operations or life, or to satisfy new requirements.
- **Special Activity** – The authorized short-term or limited collection of data (special sampling), system or equipment installation, equipment relocation, equipment modification system testing, and other similar activity for a specific purpose.
- **Preventive/Routine Maintenance** – Maintenance actions performed on systems, equipment, or facilities to ensure continued operation within the prescribed capabilities and/or minimize failure probability. Routine maintenance includes scheduled, planned, or periodic preventive maintenance actions.

An EMRS program is essential to maintaining critical equipment, setting staffing levels, and formulating budgets.

Software Maintenance

Most software maintenance will fall into a few general categories:

- Loading commercial software, including operating systems and applications
- Keeping current commercial software (operating systems and applications) up to date. This includes loading interim patches.
- Assisting local programmers in developing, debugging, and maintaining staff-authored computer programs, and distributing such programs to other centers
- Adapting software applications from other forecast centers to fit center needs and possibly improving the application for distribution to other centers

Hardware Maintenance

Hardware maintenance can involve work on any of the following systems, depending on the center's maintenance program philosophy and goals (for example, whether maintenance is in-house or contracted). While this list is not exhaustive, it illustrates the wide range of skills needed by the electronics staff at a center:

- Streamflow gauges
- Automated precipitation gauges and gauge networks
- PCs (operational and administrative)
- Workstations
- Servers
- Routers
- Cabling
- Firewalls
- Telephone systems, including answering machines
- Satellite uplinks and downlinks
- UHF and VHF links
- Shortwave radio transmitters

Technician Training

Electronics technicians must be proficient in at least three very distinct areas:

- Mechanical devices (e.g., tipping bucket precipitation gauges)
- Electronic devices, including microelectronics
- Software

International training is available for many types of gauge installation and maintenance. Training in software applications, including operating systems and programming, is also readily available and should be utilized whenever possible.

Training on other electronic devices like routers, satellite downlinks, and radio transmitters is more difficult to obtain but should be budgeted for, as these types of systems are crucial to center operations.

Important Points to Remember about Maintenance Programs for Flash Flood EWS

- The need for a well-coordinated and supported maintenance program is critical to the success of a forecast center's flash flood warning program.
- Whether a center operates an in-house maintenance program, contracts out all maintenance, or has a program that is a mixture of the two approaches, it must **track** all maintenance activities in order to effectively manage the program.
- A center should establish what constitutes reportable maintenance events. These are the events that should be tracked in order to maintain the center's programs.
- There is international training available for many types of earth data gauge installation and maintenance.
- Training on other electronic devices like routers, satellite downlinks, and radio transmitters is more difficult to obtain, but should be budgeted for, as these types of systems are crucial to center operations.