CHAPTER 2

UNIT DESCRIPTION

2.1 Components. This chapter contains a description of the major components of a WSR-88D unit. The major components are:

Radar Data Acquisition
Radar Product Generator
Associated Principal User Display Systems
Communications

Each component is discussed in general terms in this chapter. For a more detailed description, refer to the WSR-88D technical manuals. In the case of associated principal user display systems, refer to the technical manuals of the respective display system.

2.2 Radar Data Acquisition. The RDA provides the detection and measurement of meteorological and hydrological phenomena. The RDA functional area consists of the hardware, firmware, and software required to control the antenna, transmit and receive radio frequency pulses, perform signal processing, ground clutter suppression, range unfolding and distribute base data in the form of three base moments (reflectivity, mean radial velocity, and velocity spectrum width) to the RPG. The RDA also provides the capability for calibration, status monitoring, and error detection in support of both operations and maintenance activities (both local and through the Federal Aviation Administration (FAA) Remote Monitoring Subsystem (RMS)).

The RDA is composed of the antenna, pedestal, radome, facilities, transmitter, receiver, signal processor, user interfaces, and communications. Basic information on each of these is provided below. Additional detail can be found in the RDA technical manuals and Part B of this Handbook.

2.2.1 Antenna. The antenna uses a parabolic reflector, 8.5 m (28 ft) in diameter, to provide a beam width of approximately 0.93^{o}. The antenna feed horn applies linear horizontal polarization to transmit and receive S-band radio frequency (rf) pulses. Return signals from weather echoes are routed to the receiver and converted for use by the signal processor.

2.2.1.1 Polarization. In addition to frequency, an electromagnetic wave has a property called its state of polarization, which describes the behavior of the electric field component. The electric field component of an electromagnetic wave is perpendicular to the direction of wave propagation. The constantly changing orientation of the electric field component with respect to the direction of propagation defines the polarization of the electromagnetic wave. In general, the electric field traces out an ellipse as the wave propagates through space. Circular and linear polarizations are special cases of polarization of interest in radar technology. Circular polarization is characterized by an electric field of constant magnitude that rotates around the axis of propagation; linear polarization is characterized by an electric field that oscillates in a plane.

Linear polarization can be further characterized by the orientation of the plane of oscillation, e.g., linear horizontal or linear vertical. An electromagnetic wave is said to be unpolarized when the electric field component appears to fluctuate randomly.

Polarized waves are used in radar applications to improve target detection. The WSR-88D employs linear horizontal polarization to enhance liquid precipitation detection. As liquid precipitation falls, it tends to flatten, giving it the appearance of an oblate spheroid. Linear horizontal polarization takes advantage of the resultant exaggerated horizontal cross-section of the rain drop.

2.2.1.2 Volume Coverage Patterns. To adequately sample the atmosphere within the range of the radar, the WSR-88D unit employs several scanning strategies, which are implemented as Volume Coverage Patterns (VCPs). A VCP is a series of elevation angles completed within a specified period of time. Each VCP has distinct elevations, Pulse Repetition Frequency (PRF), and rotational speed requirements. The VCPs designed for precipitation detection implement three distinct waveforms to allow for long-range detection of reflectivity and a high Nyquist interval to reduce velocity aliasing. In general, the lowest two elevation angles are scanned twice. The first scan uses a contiguous surveillance waveform and the second uses a contiguous Doppler waveform. This is done to resolve ambiguities of velocity aliasing and range folding and to allow for better clutter suppression. The middle elevation scans employ a combined waveform called "batch mode" that provides estimates of reflectivity and Doppler moments. The higher elevation scans use a contiguous Doppler waveform without range unfolding since measurements of reflectivity at long range are not required at those elevations. (See Part C, Chapter 5, of this Handbook for a more complete explanation and detailed description of these scans.)

Table 2-1 shows the relationships between long and short pulses, Precipitation and Clear Air Modes, and surveillance and Doppler data sampling.

Table 2–1
Relationships

Data Averaging (Precipitation Mode)	[samples per bin]
Surveillance	3-28
Doppler	25-111
Data Averaging (Clear Air Mode)	[samples per bin]
Surveillance (long pulse)	63
Doppler (long pulse)	87
Surveillance (short pulse)	11-64
Doppler (short pulse)	220-278

2.2.1.2.1 Short Pulse. Short pulse is used in VCP 32 in the Clear Air Mode (scanning of 5 elevation angles completed in 10 minutes); and VCPs 11 (14 elevation angles in 5 minutes), 12 (14 elevation angles in 4.1 minutes), 21 (9 elevation angles in 6 minutes), and 121 (9 elevation angles in 5 minutes) in the Precipitation Mode. The pulse length is 1.57 µs or ~250 m and is used in conjunction with PRFs ranging from 318 to 1304 pulses per second.

2.2.1.2.2 Long Pulse. Long pulse is used in VCP 31 when operating in the Clear Air Mode. As in VCP 32, 5 elevation angles are scanned in 10 minutes. The long pulse is 4.7 µs or ~0.75 km (0.4 nm) and is used in conjunction with a PRF of 318 to 452 pulses per second. Long pulse results in enhanced sensitivity and can measure weaker return signals. Using the simple ratio of the increase in pulse depth as a measure of the increased energy provided to the return, we could expect an increase in signal to noise ratio of about 4.2 dB. In addition, the system attempts to provide an equivalent to a matched filter for the long pulse through an averaging process. However, due to losses in the process rather than achieving the theoretical increase of 8.4 dB, the increase in sensitivity of long pulse to short pulse is approximately 6 dB.

2.2.2 Pedestal. The antenna pedestal is an aluminum and cast iron structure that positions the parabolic antenna in both azimuth and elevation. In an operational mode, the antenna rotates continuously in azimuth at a maximum speed of 5 revolutions per minute (RPM) (while the pedestal is capable of 6 rpm) and moves in incremental steps in elevation at the rate of one step per azimuth revolution. The physical limits on the antenna elevation are -1^{o} and +60^{o}. The operational VCPs cover elevation angles from 0.5^{o} to 19.5^{o}.

2.2.3 Radome. The radome, which protects the antenna and pedestal from weather hazards, is of rigid fiber glass construction with a diameter of 11.9 m (39 ft) and an rf two-way loss of 0.6 decibel (dB) at 2,800 megaHertz (MHz). Its design inhibits ice and snow buildup. The radome is coated with a hydrophobic paint which sheds water readily. The radome has maintenance heating, forced air ventilation, and aircraft warning lights, when required. The radome is also equipped with a lightning protection system consisting of either a single air terminal and associated grounding system or an array of multiple air terminals for selected configurations.

2.2.4 Facilities. The facilities include buildings, towers, power generation, and air conditioning equipment. The WSR-88D tower is of steel construction and assembled in increments of 5 m. The engine generator is housed in a separate enclosure, as is the RDA and RPG (where collocated), and any redundant radar and support equipment. Support equipment for the tower includes prime power distribution, backup power, a transition power system, environmental control (heating, ventilating, and air conditioning), and remote sensors for security and environmental equipment failures.

2.2.5 Transmitter and Receiver. The transmitter is a high-power, S-band, pulse amplifier that generates the rf pulse for transmission via the antenna. Input to the transmitter is a gated, low-power (10 milliwatts) rf drive signal with a frequency range of 2,700 to 3,000 MHz, which is generated by the receiver. The signal provides coherency (phase reference) for the return signal from which to compute the Doppler phase shift. The Klystron transmitter then transmits a burst of high-power rf energy of either 1.57 or 4.7 microseconds (µs) in duration, with a peak operating power of approximately 750 kilowatts. The high-power rf energy is transmitted to the antenna through a waveguide.

The receiver sends the rf amplified signal and synchronization signals to the transmitter, amplifies the rf signal from the antenna, and transfers the analog data to the signal processor. It sends signals to and receives commands from the RDA Status and Control (RDASC) program.

2.2.6 Signal Processor. The signal processor accepts the analog data from the receiver and processes the data into base data that are sent to the RDA control. The processing is accomplished using a hardwired signal processor (HSP) and a programmable signal processor (PSP).

2.2.6.1 Hardwired Signal Processor. The functions of the HSP are to convert analog data into digital data, perform clutter filtering, and maintain system synchronization. The HSP processes and outputs the radar data on a 0.25 km (0.13 nm) gate-by-gate basis and sends these data to the PSP.

2.2.6.1.1 Analog to Digital Conversion. The analog-to-digital (A/D) converter assembly is physically part of the receiver (for low noise considerations), but is functionally considered to be part of the signal processor. The A/D converter accepts analog in-phase (I) and quadrature (Q) and logarithmic (LOG) inputs and converts them to 12 bit two's complement at a 0.6 MHz rate (0.25 km (0.13 nm) sampling interval). The converter has test/bias digital inputs that provide two functions. During normal operations, these inputs are used to null out direct current biases, which would degrade base data. During A/D tests, these inputs inject test signals.

The A/D converter outputs I, Q and LOG on three serial interfaces at a 9.6 MHz rate (burst of 12 bits per range bin). All signal processor interfaces are isolated from the receiver with opto-isolators to reduce the effects of digital noise on the receiver sensitivity.

2.2.6.1.2 Clutter Filtering. The WSR-88D provides for the suppression (reduction) of returned power whose radial velocity falls within the specified "notch width" (range of velocities centered on zero) within predefined areas. Basically, the larger the notch width the greater is the reduction in near-zero velocity signal power (suppression). This reduction in signal power effectively decreases the clutter's power contribution in the given range bin. To maintain meteorological return integrity, only the signal power whose radial motion falls within the notch width is reduced.

The HSP uses a site-unique Bypass Map (built by the RDA System Operability Test (RDASOT) software), Default Notch Width Map (Master System Control Function (MSCF)-controlled RDA adaptation data), and operator-defined Clutter Suppression Regions to determine the areas in which to invoke suppression, and the amount of suppression (signal reduction) to apply.

The Bypass Map and Default Notch Width Map are used to identify and suppress areas of known ground clutter return. In the absence of any operator-defined Clutter Suppression Regions, the WSR-88D will use the Bypass Map to determine where to apply clutter suppression and the Default Notch Width Map notch width definitions (stored RDA adaptation data) to determine the amount of suppression to be applied.

In accordance with Unit Radar Committee (URC) guidelines, as specified in Part A of this Handbook, the MSCF operator may modify the application of clutter suppression to known ground clutter areas and transient areas through the definition of Clutter Suppression Regions. Inappropriate application of operator-defined Clutter Suppression Regions can result in degradation of data accuracy and quality.

The WSR-88D detects only the radial component of the actual target motion. Therefore, if the target is moving perpendicular to the radar beam it has a zero (or near zero) radial motion. If clutter suppression has been invoked for a given range bin whose radial target motion is zero (or near zero), the defined power reduction factor will be applied to that bin. This power reduction will result in a significantly reduced reflectivity estimate for the range bins whose mean radial velocity is at or near zero.

In areas with a strong azimuthal reflectivity gradient, clutter suppression may result in an artificial displacement of the returned power maxima into azimuthally adjacent range resolution cells. This data smearing is an artifact of the clutter filter response times and occurs when high reflectivity gradients are present. The clutter filter decay rate is slower with narrower notch widths; therefore, data smearing is more likely to be seen when low suppression levels are used. When data smearing occurs, weak reflectivity features on the trailing edge (azimuthally) of a high reflectivity gradient may be obscured. Additionally, the apparent aerial extent of high reflectivity will be increased. The impacts of data smearing on the velocity and spectrum width estimates vary depending upon the relative power contributions from the range resolution cells for the affected range bin.

Appropriate application of clutter suppression, however, will result in several improvements in WSR-88D data quality and operations. The most obvious benefit attained as a result of proper clutter suppression is that ground clutter is removed from the graphical products displayed at the user display system or workstation. However, several more important data quality improvements can be realized by the optimum application of clutter suppression.

The most important benefit is the improved accuracy of the WSR-88D products. Since clutter suppression occurs prior to the calculation of the base data estimates, proper clutter filtering will result in the base data estimates being more representative of the actual meteorological situation. Consequently, the more accurate the base data estimates, the more reliable the output from downstream processing and algorithms and, as a result, the more accurate base and derived products.

By removing (reducing) the power contribution of ground targets from the base data estimate for first-trip range bins, the likelihood of assigning valid velocity and spectrum width data to second-trip range bins is increased.

A large number of velocity dealiasing failures that occur in VCP 31 can be attributed to ground clutter induced bias in the base velocity estimate. The removal of the ground clutter bias from the base velocity estimate will result in meteorologically plausible ambiguous velocity estimates. These ambiguous velocity estimates can then be readily dealiased by the dealiasing algorithm. However, residual ground clutter will continue to cause velocity dealiasing algorithm failures.

The Clear-Air Mode deselection logic employed by the WSR-88D compares the area coverage of precipitation-like return to a specified value (nominal clutter area plus precipitation area threshold). If the area coverage of precipitation-like return exceeds this value, the RPG computer commands the RDA computer to switch to Precipitation Mode. The reduction of non-meteorological data from the aerial coverage computation will result in a more accurate estimate of the actual precipitation present, thereby reducing the likelihood of prematurely switching to Precipitation Mode due to ground clutter returns.

2.2.6.1.3 System Synchronization. Synchronization provides computer controlled range counters and range decoding logic to generate timing triggers, clocks, and gates for the transmitter, receiver, and the signal processor. It also provides computer controlled radial sequence counters and decoding logic to control radial timing to generate radial clocks. The range counter and radial counter logic, in combination, generate contiguous surveillance, contiguous Doppler, and batch waveforms.

For each waveform type, the radial consists of a specified number of pulses. The PRF, the number of PRFs, and the azimuth scan rate control the azimuthal extent of the radial. Radials normally have an azimuthal extent of one degree.

2.2.6.2 Programmable Signal Processor. The PSP receives time-series digital data from the HSP and develops the echo power, reflectivity, mean radial velocity, and spectrum width arrays. These arrays are sent to the RDASC processor where base data are formatted and stored. Within the PSP, point clutter suppression and range unfolding are performed. These base data are then sent back to the RDASC and header information (time, azimuth, elevation, and calibration parameters) is attached prior to transmission to the RPG.

2.2.6.2.1 Strong Point Clutter Suppression. In the PSP, strong point clutter suppression is accomplished by computing a digital estimate of the power sum for each sample volume. The PSP analyzes the power sum array to detect strong point clutter. The PSP replaces the power data in sample volumes having abnormally high return power with values calculated from nearby unaffected sample volumes. These power sum array data are then processed to compute the base data.

2.2.6.2.2 Range Unfolding. The WSR-88D uses three techniques to resolve range folding. The first technique, used at the lowest two elevation angles, scans each elevation angle twice. The first scan uses a contiguous surveillance waveform and the second scan uses a contiguous Doppler waveform. The contiguous surveillance scan generates an echo power array with 0.5 dB and 1 km (0.54 nm) resolution for each radial. This reflectivity information is sent to the RDASC as each radial is collected. The echo power arrays are stored in the RDASC until the end of the surveillance scan and are then sent back to the PSP, radial by radial, while the PSP processes the contiguous Doppler scan for the same elevation angle. The PSP compares the radial information collected during the contiguous Doppler scan to the corresponding radial information collected during the surveillance scan to correctly correlate areas of Doppler data with areas of reflectivity data. The PSP combines the surveillance and Doppler data into a single record labeled as "Doppler data."

The second technique is called "batch mode." Batch mode employs interlaced surveillance and Doppler waveforms to achieve the required range while allowing the radar to simultaneously collect base reflectivity, mean radial velocity, and spectrum width data. This technique is used at intermediate elevation angles where multiple trip returns can occur in the Doppler waveforms, but where clutter suppression is not normally required as at the lower elevation angles. Velocity data are range unfolded in essentially the same process as described above.

Since very little weather occurs above 21.3 km (70,000 ft), velocity data range folding at higher elevation angles is not an operational problem. Because the height requirement is obtained within the unambiguous range of the high PRFs, estimates for reflectivity, mean radial velocity, and spectrum width are achieved using contiguous Doppler waveforms.

The third technique uses the Multiple PRF Dealiasing Algorithm (MPDA). The MPDA scanning strategy collects sequential scans at the same antenna elevation angle using different Nyquist velocities (PRFs). These are then range dealiased, aligned, and processed to produce a final dealiased velocity field based on the combined scans. The actual unambiguous ranges and corresponding Nyquist velocities depend on the operating frequency of the radar and may be expressed as follows:

$$R_{\mathbf{a}}V_{\mathbf{a}} = c^2/(8\boldsymbol{f})$$

where c is the speed of light, $\boldsymbol{f}$ is frequency, $R_{\mathbf{a}}$ is the unambiguous range, and $V_{\mathbf{a}}$ is the Nyquist velocity.

The MPDA requires a new VCP, VCP 121. Volume Coverage Pattern 121 requires three Doppler scans, besides the surveillance scan, at both 0.5° and 1.5° elevation; two additional Doppler Scans in addition to the batch mode scans at 2.4° and 3.3° elevation; and one additional Doppler scan at 4.3° elevation. Above 4.3° elevation, VCP 121 is identical to VCP 21. Additional information on VCP 121 can be found in Part C, Chapter 5, of this Handbook.

2.2.7 User Interfaces. The RDA is controlled by the RDASC program. It monitors and assesses the performance of the RDA, initiates automatic calibration, performs calibration calculations, and reports RDA status to the RPG. It formats reflectivity, mean radial velocity, and spectrum width data input from the signal processor, attaches header data, and initiates data transfer to the RPG.

The RDASC program provides the capability to operate under local control or unattended remote control. Under local control, it sets the RDA mode and performs the various startup and shutdown procedures, based on control inputs from the maintenance console. Under unattended remote control, the same operations are performed in response to the control inputs from the MSCF. The program generates the pedestal control commands, closes the position loops of the pedestal, and serves as the control processor for the PSP.

2.2.8 Communications. A wideband communications link exists between the RDA and the RPG. This link supports the synchronous, bidirectional, full duplex communications of data between the RDA and the RPG. For additional information, see Section 2.5.

2.3 <u>Radar Product Generator</u>. The RPG provides real-time generation, local storage, and distribution of WSR-88D products and base data. The RPG also includes hardware and software required for base data ingest from the RDA, control, and status monitoring and error detection. The RPG processes base data from the RDA and processes meteorological and hydrometeorological products by execution of resident algorithms.

The RPG also provides the capability to control RDA operational modes and VCPs and to monitor WSR-88D unit status. Status and error messages from the RDA and RPG are stored and any status changes in the RDA or RPG are sent to the Associated User display system.

The major hardware components of the RPG are the computer processors, the MSCF, and equipment to support wideband and narrowband communications.

2.3.1 Master System Control Function. The main screen of the RPG Graphical User Interface (GUI) is the primary software application the operator uses to interact with the MSCF terminal. While part of the function of the GUI is to provide a launch point to various system control windows (applications), it is important to note that a great deal of significant system information can be obtained from this screen. The vital information necessary to determine the overall operability of the system is available at a glance. The MSCF, via the GUI, provides control and monitoring of the RPG, the RDA, and communications.

Sets and subsets of products to be generated, distributed, and placed in mass storage can be selected. In addition, modifications to adaptation parameters of the following functions can be made at the MSCF:

1. Products sent in response to one-time requests from a Non-Associated User,

2. Task priority for load control at the RPG when overload conditions occur,

3. Load control across communications lines from the RPG when overload conditions occur,

4. Thresholds for RPG usage levels that, when exceeded, result in a warning message at the MSCF,

5. Product-alert pairing, and

6. Meteorological and hydrological algorithms.

The MSCF provides the interface with the RPG computer to perform functions such as initialization, rebooting, startup of unit software, and various disk operations.

The different types of status information available at the RPG GUI are listed below and depicted in Figure 2-1.

1. **RDA Alarms -** Whenever alarm conditions are present at the RDA, an indication descriptive of the alarm type will appear in the upper left portion of the GUI.

2. **Current Azimuth and Elevation Angle -** The thick black line on the radome perimeter shows the beginning through the current antenna azimuth for the present elevation cut. The value in the center of the radome (along with the emanating yellow beam) shows the antenna's current angle.

3. **RDA State/Operability Status -** Shows the RDA operational state and operability status.

4. **Current VCP/wx mode -** Indicates which of six VCPs (11, 12, 21, 121, 31, 32) is currently in use. The beams emanating from the radome also provides this information:

1 VCPs 11, 12 = 14 beams / elevation angles

2 VCPs 21, 121 = 9 beams / elevation angles

3 VCPs 31, 32 = 5 beams / elevation angles

5. **Current volume start time -** Indicates the date and time at which the current volume scan began.

6. **RDA Control -** Indicates where control of the RDA resides (remote [i.e., RPG/MSCF] or local [RDA/Man Machine Interface (MMI) or FAA RMS]):

1 EITHER means the RDA is in Standby and either remote or local can take control.

2 RPG: The RDA is controlled remotely. (RPG/MSCF)

3 RDA: The RDA is controlled locally. (RDA/MMI or FAA RMS)

7. **RPG State/Mode -** Shows the current RPG State (Operate, Standby, and Shutdown) and the mode in which it is operating. A state of "Transition" will be displayed during the time period the RPG is changing from one of the three states to another. RPG mode can be either Operate or Test.

8. **RPG Alarm -** Present whenever maintenance required and/or maintenance conditions exist.

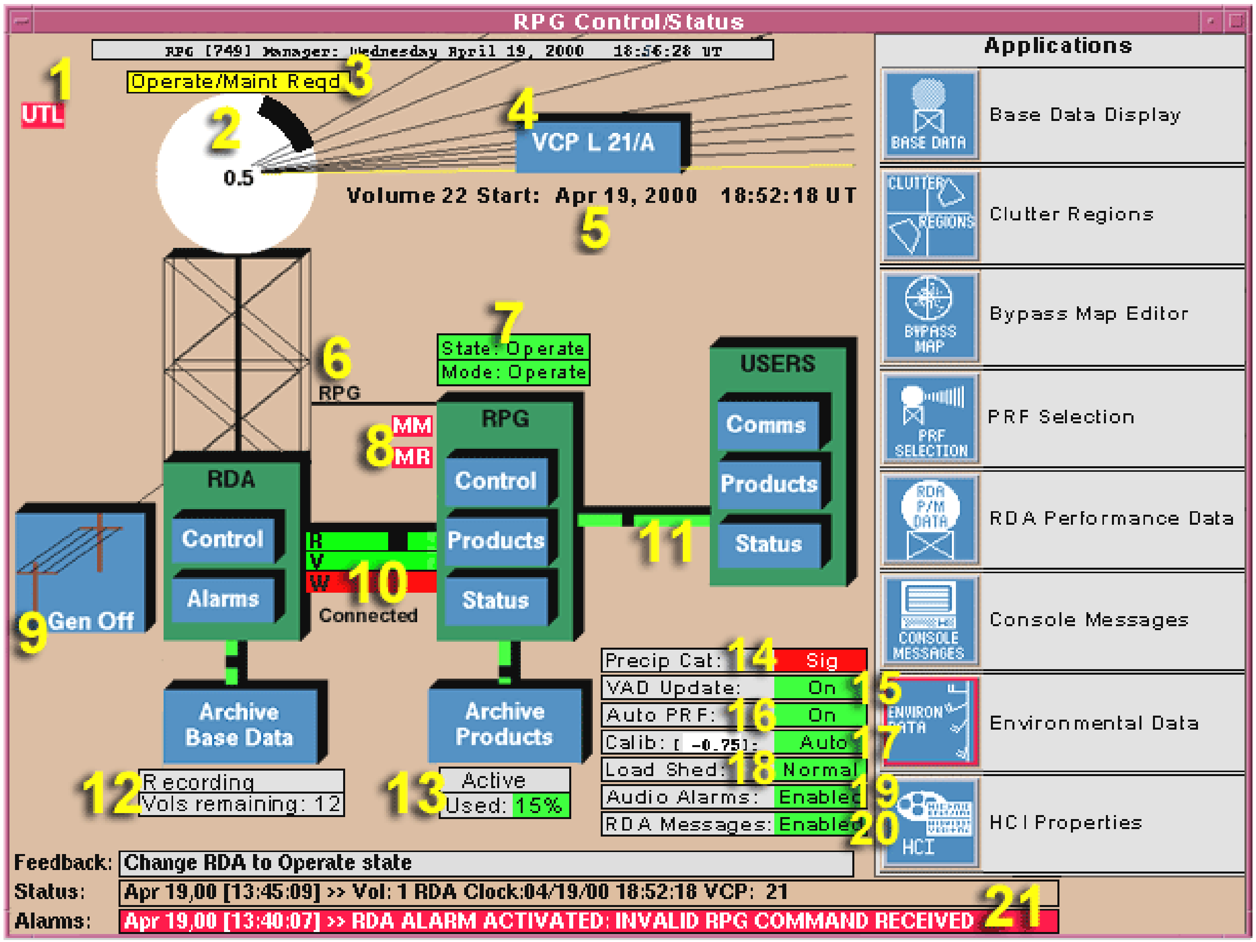

Figure 2-1
RPG Graphical User Interface

Status Indicators Within the RPG Graphical User Interface (GUI). The overlayed numbers (in yellow) correspond to those discussed in the text.

9. **Power Source -** The power source is indicated by the presence of either telephone poles/power lines (utility) or a generator shelter (indicating the generator as the power source). If the selected power source was the generator, and utility power source were available, a textual indication (Utility Power Available) would be displayed.

10. **Wideband Status -** Displays the current status of the RDA - RPG Wideband communications link.

Also displayed is the data transmission enabled status (whether or not the data for a given moment will be sent from the RDA to the RPG) for each of the three base moments.

1 Green means enabled.

2 Red indicates that the transmission of a particular moment or moments has been disabled.

11. **Product Distribution Comms -** Indicates the current state of Product Distribution Communications (formerly referred to as Narrowband Communications).

12. **Archive II –** Recorded off site.

13. **Archive III –** Recorded off site.

14. **Precipitation Category -** Shows the current Precipitation Category as either significant, light or none.

15. **Auto VAD Update -** Indicates whether the Auto Velocity Azimuth Display (VAD) Update function is turned ON or OFF.

16. **Auto PRF -** Indicates whether the Auto PRF function is turned ON or OFF.

17. **Delta System Calibration -** Displays the current Delta System Calibration value and indicates whether or not Auto Calibration is enabled (Auto) or disabled (Manual).

18. **Load Shed Status -** Indicates whether or not the utilization rate of one (or more) of the 6 load shed categories has breached either the warning or alarm thresholds (alarm takes precedence over warning).

19. **Audio Alarms -** Indicates whether Audio Alarms (for conditions monitored by the RPG) are Enabled or Disabled.

20. **RDA Messages -** Indicates whether reception of text messages sent from the RDA is Enabled or Disabled.

21. **System Status/Alarms -** The Status line displays the most recent system status change - a corresponding entry will be submitted to, and can be displayed from, the system status log. The Alarms line shows the most recent alarm condition that has developed within the system. Since the occurrence of an alarm condition also represents a change in status, an alarm condition also warrants an entry in the status line.

2.3.2 Archive II and III.

2.3.2.1 Archive II. These data, defined in Part A of this Handbook and also known as "Level II," are not recorded on site. These data are routed to the 4 ports on the Base Data Distribution System (BDDS), at all DOC and DoD Contiguous United States (CONUS) sites, where users can receive the data. The Level II data stream also contains metadata which describe the data and the operating conditions of the radar when the data were generated. Level II data, from all DOC and 13 DoD CONUS sites (currently), are sent electronically to the NCDC for meeting NWS data archive requirements, National Centers for Environmental Prediction (NCEP) for NWS real-time operational requirements, and are readily available to other users in real time.

2.3.2.2 Archive III. These products and data, defined in Part A of this Handbook and also known as "Level III," are no longer recorded on site, but are sent (along with specified additional products and data) from all DOC radars to the NCDC archives via the NWS Advanced Weather Interactive Processing System (AWIPS) and NWS Radar Product Central Collection Dissemination Service (RPCCDS). (The list of the products collected is available at: http://www.nws.noaa.gov/ops2/prodserv.html.) The same set of products and data are sent to the NWS RPCCDS and the NCDC, from all DoD and DOT radars except for 4 remote overseas DoD radars.

2.3.3 Radar Product Generator Communications Equipment. A wideband communications link exists between the RDA and the RPG. The RPG narrowband communications links include modem interfaces to Associated and Non-Associated Users, Other Users, and remote or local MSCF. (For additional detail about communications, see Section 2.5.)

2.3.3.1 Wideband Communications Equipment. See Section 2.5 for details in regard to wideband communications.

2.3.3.2 Narrowband Communications Equipment. Narrowband communications use 2- or 4-wire, leased lines and 2-wire, switched lines. The 2- or 4-wire, leased lines are used for communications with the MSCF, and an associated principal user display system and between the RPG processor and a remotely located MSCF. The 2-wire, switched lines are used for dial-up communications with Non-Associated Principal User Display Systems.

Narrowband communications equipment sends and receives selected products, alarms, and status and command messages to and from Associated and Non-Associated Principal User Display System and Other Users.

Narrowband communications using 4-wire leased lines are used to support Frame Relay service. Frame Relay service is a high-performance Wide Area Network (WAN) protocol that operates at the physical and data link layers of the Open Systems Interconnection (OSI) reference model.

Frame Relay is a packet-switched technology. Packet-switched networks enable end stations to dynamically share the network medium and the available bandwidth. Frame Rrelay service equipment consists of the Frame Relay Hub Router located at the NWS Weather Forecast Offices controlling DoD and FAA radars and a Channel Service Unit/Data Service Unit (CSU/DSU) module installed in all RPG Routers.

2.4 Associated Principal User Display Systems. The NEXRAD agencies used the PUP as the standard WSR-88D display device when the network was first deployed. In order to meet agency-unique WSR-88D data display and processing requirements, the NEXRAD agencies have migrated to a new generation of display systems which are considered Associated Users, as were the PUPs. The display capabilities and default display parameters of each system vary. Below is a summary of the primary NEXRAD agency associated Principal User Display Systems connecting to RPGs:

2.4.1 Advanced Weather Interactive Processing System. The NWS's AWIPS is a distributed data processing system used at field offices, regional offices, River Forecast Centers, national centers, and NWS Headquarters to integrate information received from all other observational and analytical elements of the NWS Modernization. The AWIPS also provides a nationwide communications network for distributing weather data, products, and services.

2.4.2 Weather and Radar Processor. The FAA's Weather and Radar Processor (WARP) is an FAA computer network that displays WSR-88D product data on air controllers' displays in Air Route Traffic Control Centers (ARTCCs). The WARP also collects, formats, and distributes weather information to Center Weather Service Units at FAA ARTCCs.

2.4.3 Integrated Terminal Weather System. The FAA's Integrated Terminal Weather System (ITWS) provides terminal aviation system users with safety and planning products that characterize current terminal weather situations as well as forecast about 30 minutes into the future. The ITWS integrates data from the WSR-88D, Terminal Doppler Weather Radar (TDWR), Airport Surveillance Radar-9 (ASR-9), Low-level Windshear Alert System (LLWAS), Automated Surface Observing Systems (ASOS), and other NWS systems.

2.4.4 Open System Principal User Processor. The OPUP Program was started in 1996 as a direct replacement to the PUP. The OPUP is maintained as the WSR-88D baseline display system. The OPUP provides the capability to request products from the RPG; display, manipulate, and locally store products; monitor the status of the RPG and RDA; and perform archival functions. The OPUP has evolved into three separate sized OPUPs to support various missions.

The Small OPUP is a direct replacement for the legacy PUP at select Air Force and Navy locations. It consists of a single workstation.

The Medium OPUP supports direct connections to up to seven WSR-88Ds. They are located at centralized forecast facilities in the Pacific for the Air Force, and the East and West coasts for the Marine Corps. The medium OPUP consists of up to three workstations along with communications hardware and server.

The Large OPUP supports direct connections to up to 24 WSR-88Ds. They are located at four centralized forecast facilities across the United States. The large OPUP consists of up to 10 workstations along with communications hardware and a server.

2.5 <u>Communications</u>. The WSR-88D communications equipment supports wideband and narrowband communications between the RDA and RPG and the RPG and OPUP/Associated User display systems, respectively.

2.5.1 Wideband Communications. The wideband communications link includes Direct Memory Access interfaces within the RDA and RPG computers, Wideband Communications Control Modules (WCCMs), Digital Communications Units, and a communications medium. Three types of media used for transferring wideband/base data, status commands, and controls are listed below. Commercial T1 links, using combinations of the following media, are used at several sites.

1. Wire - used when the RDA and the RPG are up to 122 m (400 ft) apart

2. Fiber optics – the transmitter uses either a laser or a light-emitting diode light source, depending on the length of the link. The WSR-88D fiber optic transceiver components and cable design can support a fiber cable distance of up to 2 km (1.2 mi).

3. Microwave Line of Sight (MLOS) - consists of a transmitter and receiver that are shielded against electromagnetic interference and encased in a single radio rack. A dish antenna is used for MLOS transmission and reception. Range considerations for this type of medium, without a repeater, are separation of the RDA and the RPG of up to 22 nm (41 km).

Wideband communications support three types of data exchange:

1. Data transfer between processors - data are transferred between the RDA and the RPG by direct memory access at a rate of 1.544 megabits per second over full-duplex, synchronous lines

2. Control commands from the processors to the WCCM and link equipment - control of the wideband communications link is executed by writing commands to the control

module. These commands make transfer of data between the computer and the link possible

3. Status information from the communications equipment to the processors - a report is provided when a change in status of the communications link occurs. Error detection in the communications link is provided for by the WCCM, which resides on a circuit board internal to the computer chassis.

2.5.2 Narrowband Communications. Narrowband communications include links to and from the RPG and Associated Users; MSCF; and other non-Associated Users. Ports for narrowband links are designated as dedicated, which is a full time connection; dial-up, which refers to a dial-in, part time connection; or Frame Relay, which is a full time connection.

Frame Relay and analog service to and from the RPG are used for product dissemination, commands, control and data request between the RPG and various associated Principal User Display Systems. Data are transferred at various rates, depending on the location of the user display system. The MSCF equipment is connected to the host RPG by either a X.25 dedicated analog circuit or a Frame Relay circuit.

Most, but not all, DoD and FAA sites use Frame Relay service. Frame Relay service is not used at all sites because it cannot be obtained at every location. Where Frame Relay service is used, the Frame Relay Hub Router supports Frame Relay circuits that have replaced modem interfaces using X.25 dedicated analog circuits. The Frame Relay circuits are used to send radar products to AWIPS and to control and command DoD and FAA radars (MSCF data). Frame Relay service also supports One Time Requests (OTR) from DoD and FAA radars via the AWIPS WAN.