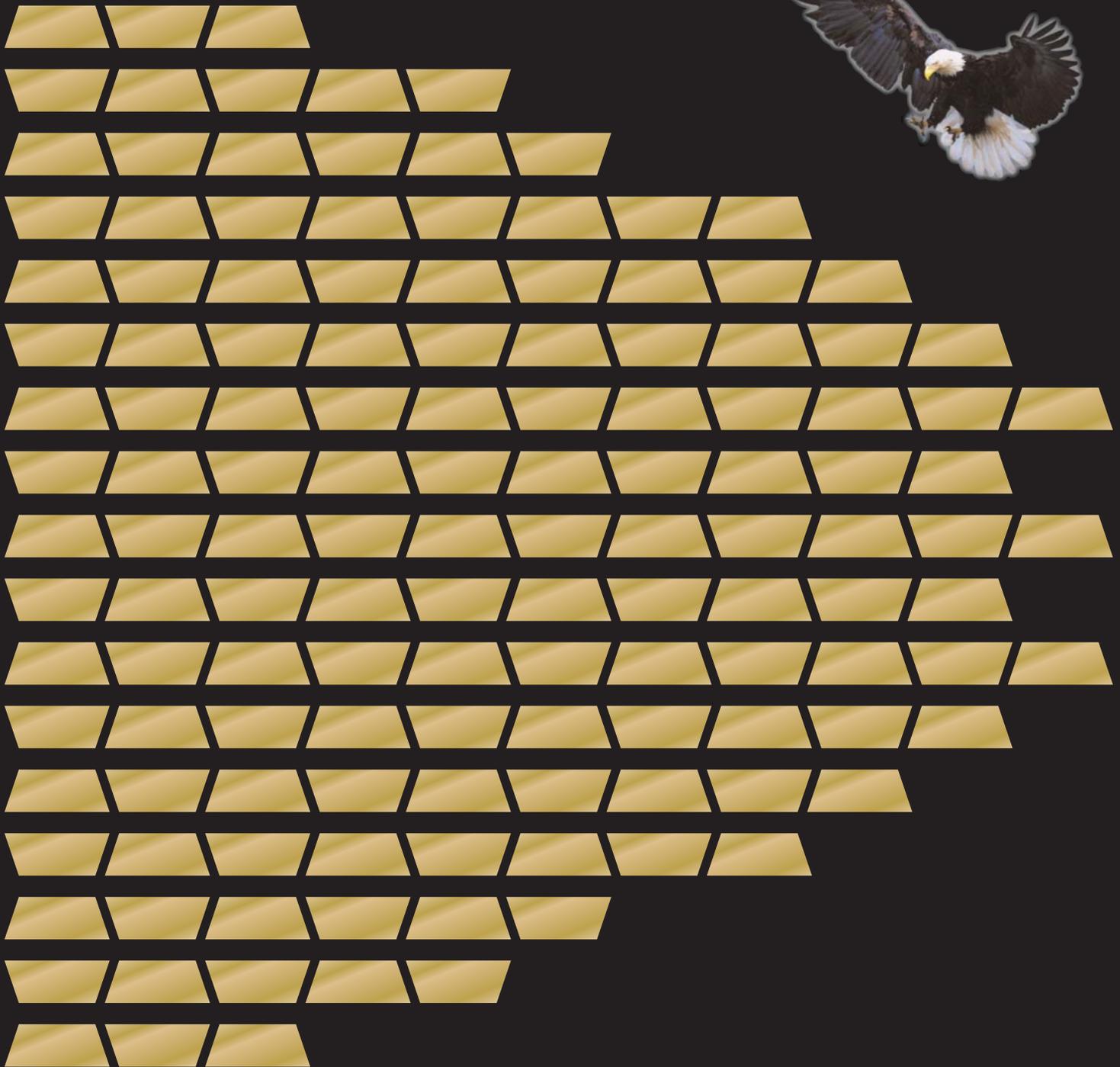


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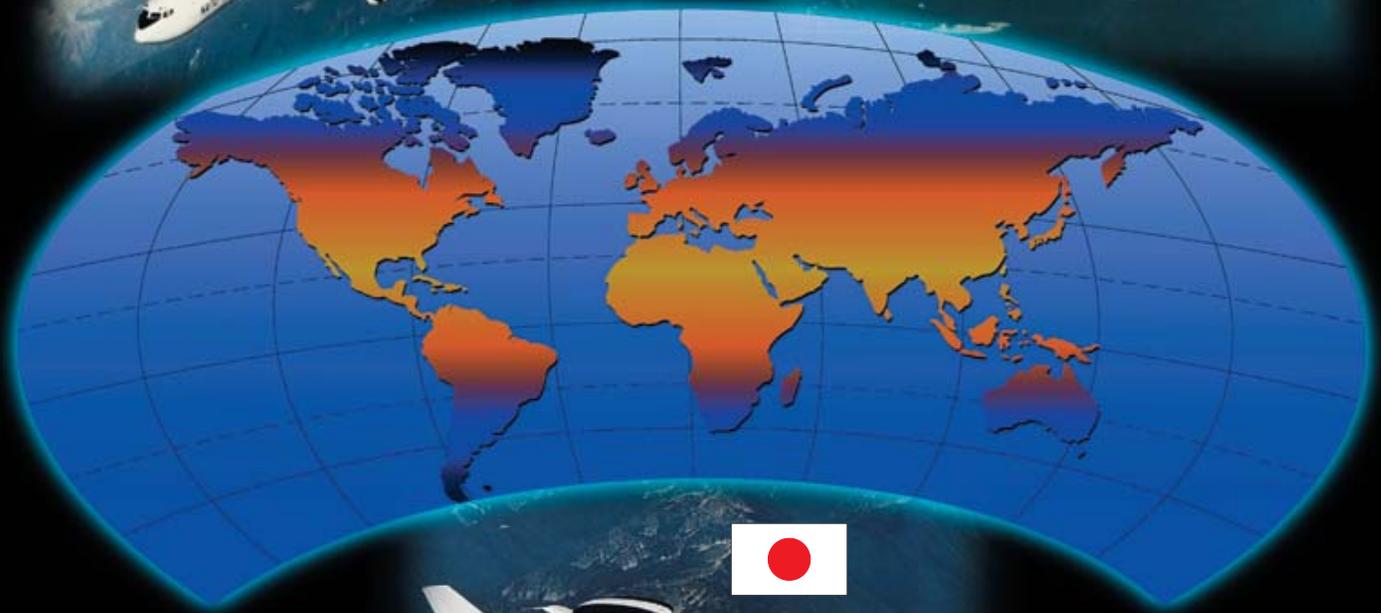
Electronic Systems

AWACS Surveillance Radar

The Eyes of the Eagle



AWACS Surveillance Radar



A Heritage of Leadership

The E-3 Sentry is an Airborne Warning and Control System (AWACS) aircraft that provides all-weather surveillance, Command, Control and Communications needed by commanders of air tactical forces. Proven in wartime operations such as Desert Storm, Allied Force and more recently Enduring Freedom, as well as ongoing peacekeeping and humanitarian efforts, AWACS is the premier air battle command and control aircraft in the world today.

Northrop Grumman Electronic Systems (ES) has a long heritage in the development and production of Airborne Early Warning (AEW) radars. As the supplier to Boeing for the AN/APY-1 and AN/APY-2 radar systems used on the E-3, and the AN/APY-2 radar system used on the E-767, ES has continued as a leader in the development of radar technology for airborne applications.

Mounted atop the aircraft fuselage in a rotating dome, the AWACS S-band (E-F band) surveillance radar is able to survey, in 10-second intervals, a volume of airspace covering more than 200,000 square miles (500,000 square km) around the AWACS, or greater than 250 miles (400 km) in all directions. The radar uses a high Pulse Repetition Frequency (PRF) pulse Doppler waveform to distinguish aircraft targets from clutter returns. The ultra low sidelobe antenna is an important element of technology used to obtain performance over all terrains including urban and mountainous areas. The mechanical rotation of the rotodome scans the antenna beam through 360 degrees of azimuth to cover targets in all directions. Electronic scanning of the antenna beam in elevation is used for measuring target altitude and for



E-3 AWACS: The world leader in airborne surveillance, proven in times of war and peace

stabilization of the beam for proper spatial coverage as the aircraft maneuvers.

The first production AWACS system on a modified Boeing 707 aircraft was delivered in 1977. This system is now in service with the U.S. Air Force, the North Atlantic Treaty Organization (NATO), Saudi Arabia, the United Kingdom and the French Republic. The first 767 AWACS configuration was delivered to Japan in 1998 by the Boeing/Northrop Grumman team. Combining the modernized, battle-proven AWACS mission system with a state-of-the-art aircraft ensures the ability of the AWACS system to defend the skies well into the 21st century.

In order to counter today's increasing threat sophistication, the AWACS radar has been significantly upgraded under the Radar System Improvement Program (RSIP). The RSIP modifications enhance radar performance characteristics, add new capabilities, improve the user interface,

and lower the life-cycle cost of the AWACS radar, while improving reliability.

Northrop Grumman is committed to making the best even better, and to maintaining superior AWACS performance against tomorrow's evolving threats. Modernization will ensure that the investments that made AWACS a reality will continue to provide returns for decades to come.

A Proven Force Multiplier

Historically, military planners have found situational awareness of potential hostile targets and of friendly forces to be a key component in obtaining and sustaining military superiority over adversaries. Over the years radar has proven to be the optimum technology for obtaining long range, all-weather surveillance capability. An airborne surveillance radar that can maintain situational awareness of potential targets and friendly aircraft over hundreds of square miles of airspace in any direction became a reality with the introduction of the AWACS. One cannot overstate the importance of AWACS to the security and stability of the Free World. The weapon system acts as a force multiplier, greatly

increasing the effectiveness of friendly forces performing a variety of missions.

In armed conflicts and in peace keeping operations, in offensive and in defensive missions, AWACS is often the first in and the last out, providing essential Surveillance, Command and Control capabilities throughout the duration of the operation.

During the Cold War, E-3 Sentries maintained constant vigil in the skies over Central Europe and the Far East.

E-3 Sentry aircraft were among the first to deploy during Operation Desert Shield where they immediately established an around-the-clock radar screen. During Desert Storm, AWACS flew more than 400

missions and logged more than 5,000 hours of on-station time, providing radar surveillance and control for more than 120,000 coalition sorties. In addition to providing senior leadership with time-critical information on the actions of enemy forces, E-3 controllers assisted in 38 of the 40 air-to-air kills recorded during the conflict. Following Desert Storm, AWACS remained vigilant in Southwest Asia as a critical element of Operation Northern Watch enforcing U.N. Security Council resolutions.

During the Balkans campaign, AWACS was the controlling element of allied airpower. In Operation Allied Force, the E-3 Sentries logged 4,800 flight hours on 500 missions, in which they were responsible for coordinating and tracking offensive and defensive missions, searching for enemy aircraft and assuring safe separation of inbound and exiting aircraft. In addition, AWACS directed the refueling efforts of about 30 tankers orbiting over the Adriatic and provided initial search and rescue coordination.

In October 2001, history was made as the NATO alliance for the first time ever aided the U.S. in homeland defense. NATO deployed five of its E-3 Sentry Airborne Warning and Control System aircraft from Geilenkirchen, Germany to help the 552nd Air Control Wing with Operation Noble Eagle, the defense of the United States.

AWACS has been an operational asset since 1977 and is projected to be in service beyond 2035. For “The High Demand, Low Density” AWACS fleet to withstand tomorrow’s challenges, AWACS’s mission effectiveness must be enhanced through modernization and sustainment programs. The Radar System Improvement Program (RSIP) is one of many modernization programs that will ensure AWACS’s ability to continue keeping the skies safe in both war and in peace.



E-3 AWACS – The Air Warfare advantage



E-3 AWACS – A critical element of coalition operations

RSIP: Sharpening the Eye of the Eagle

The Radar System Improvement Program (RSIP) provides the most significant upgrade to the AWACS radar since its development in the early 1970s. RSIP enhances the operational capability of the AWACS radar against the growing threats posed by smaller targets, cruise missiles, and electronic countermeasures. Battle-proven in all operations since Kosovo, RSIP has demonstrated excellent performance and reliability.

RSIP introduces advanced pulse Doppler waveforms, pulse compression, and new processing algorithms implemented by hardware and software improvements that

allow the system to detect and track targets at up to twice the range of the original AWACS.

The improvement in detection performance is accompanied by impressive improvements in range and angular resolution. Range resolution is increased by up to 6 to 1, and azimuth and elevation accuracy by up to 2 to 1.

The radar's ability to respond to electronic attack is significantly improved as well. This improvement is the result of incorporating the latest technology in clutter rejection, processing, and man machine interface (MMI).

The reliability and maintainability of the RSIP-enhanced AWACS is improved to increase radar availability and reduce repair time.

RSIP provides multiple radar modes to allow for operational flexibility. Some of these modes are described below.



Multi-mode Radar: Flexibility to Watch the Skies

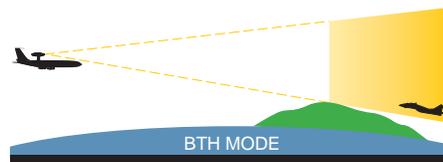
Pulse Doppler Nonelevation Scan (PDNES)

The PDNES mode provides surveillance of aircraft down to the surface by using pulse Doppler radar, with Doppler filters and a sharply defined antenna beam.



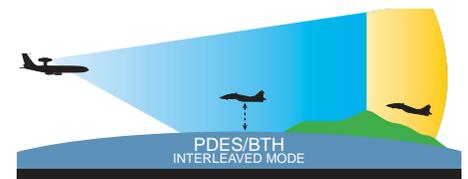
Beyond-the-Horizon (BTH)

The BTH mode uses pulse radar – without Doppler – for extended range surveillance where ground clutter is in the horizon shadow.



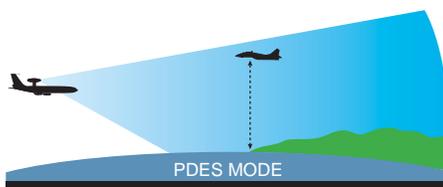
Interleaved

PDES and BTH can be used simultaneously with either portion active or passive. PDNES can be used simultaneously with maritime.



Pulse Doppler Elevation Scan (PDES)

Radar operation in the PDES mode is similar to PDNES, but target elevation is derived by an electronic vertical scan of the beam.



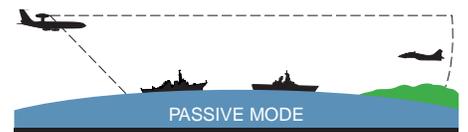
Maritime

A very short pulse is used to decrease the sea clutter patch for detection of large and small surface ships in various sea states. An adaptive digital processor automatically adjusts to variations in sea clutter and blanks land returns by means of stored maps of land areas.



Passive

The radar transmitter can be shut down in selected subsectors while the receivers continue to receive and process data. This is an effective feature in a jammed (ECM) environment. A single accurate line (strobe) passing through the location of each jammer is generated on the display console.



Designed for Performance

The AWACS surveillance radar components consist of multiple units grouped in three locations. The antenna array and its electronics are in the rotodome. The receivers, radar processors, and radar control & maintenance panel are in the main cabin. The cabin equipment consists of two cabinets for the AN/APY-1 radar (digital and analog), and three cabinets (digital, analog and maritime) for the AN/APY-2. The transmitter group is in the lower lobe of the fuselage in the aft cargo bay.

Radar Control and Maintenance Panel (RCMP)

- Two CRT displays, keyboard and trackball
- Spectrum analyzer
- Easily removable power supplies
- English language textual displays
- PPI (Plan Position Indicator) display for radar performance assessment
- FFT (Fast Fourier Transform) display

Surveillance Radar Computer (SRC)

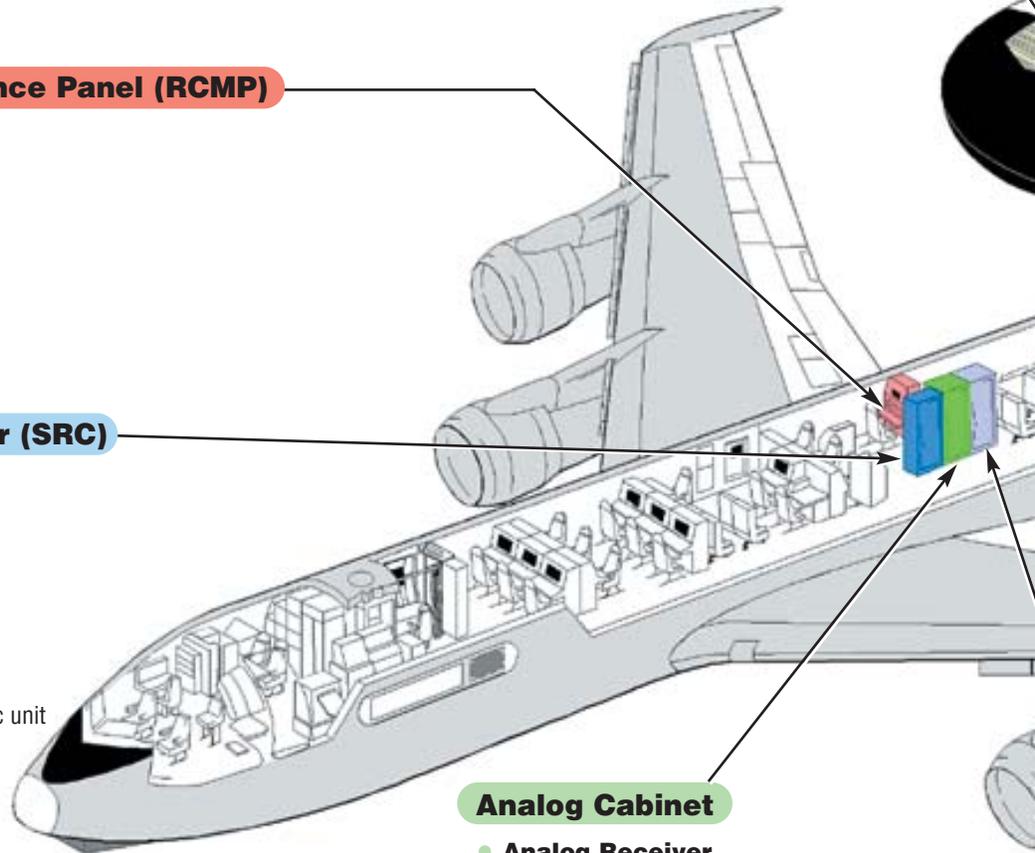
- **Adaptive Signal Processor (ASP)**
 - 24-bit precision
 - 5 MHz data rate
 - Performs over 23 billion operations per second
 - Design consists of 74 multilayered printed circuit boards of 12 types
 - Designed with 534 real pipelined arithmetic unit gate arrays (RPLAU) operating at 20 MHz
 - Flexible design with full redundancy and replanned growth capability
- **Radar Interface Adapter Unit (RIAU)**
 - Dual Redundant input/output hardware
- **Radar Data Processor (RDP)**
 - Dual VME bus-based 32-bit architecture
 - Four active processors plus one redundant processor; six input/output boards of four types
 - Each processor is a single module designed around a R4400 RISC CPU with 8 megabytes program memory plus instruction and data cache
 - Ada® programmable
 - Accommodates up to four additional processors for growth

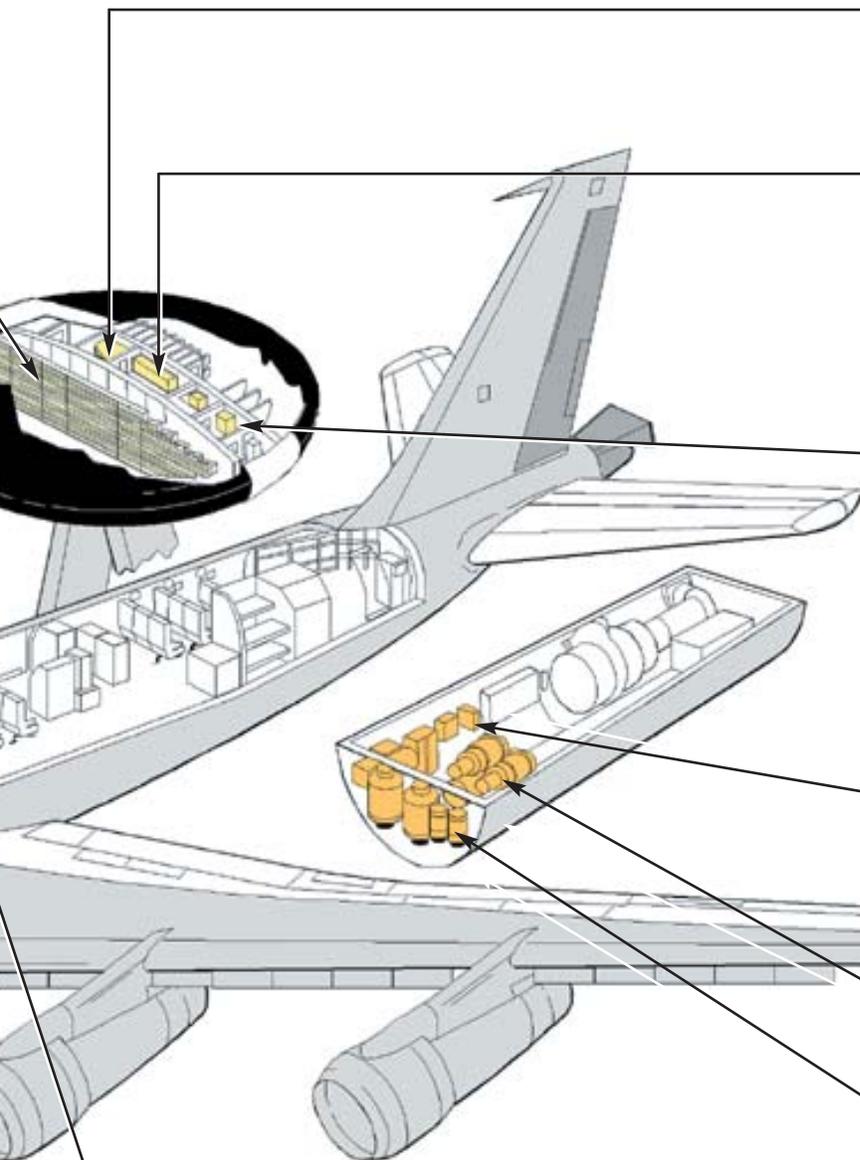
Antenna Array

- 26' (8m) x 4.5' (1.3m) Ultra-Low Sidelobe Array
- Stacked array of 28 slotted waveguides
- Reflectionless transmit and receive manifolds
- 28 reciprocal ferrite beam steering phase shifters
- 28 low-power nonreciprocal beam offset phase shifters

Analog Cabinet

- **Analog Receiver**
 - RF Assembly with redundant mixer preamplifier
 - Three Pulse Doppler IF (Intermediate Frequency) assemblies
 - PD A/D assembly with 15 bit, 5 MHz A/D converter
 - Three BTH IF assemblies
 - BTH A/D and processor assembly
 - Delay line pulse compression circuits for BTH
 - Clutter Tracker (6 circuit boards of 4 styles)
- **Synchronizer**
 - 29 circuit boards of 18 types
 - Full redundancy
- **STALO**
 - Four RF assemblies
 - Eight oscillator modules
 - Two up-conversion modules
 - Acoustic enclosure for isolation and stability
 - Phase Lock Loop (PLL) electronics





Phase Control Electronics

- **Phase Shifter Control Unit**
 - Beam angle control circuits
 - Antenna tune data storage
- **Phase Shifter Drive Unit**
 - 30 phase shifter current drive modules, two of which are redundant
- **Rotary Coupler** (not illustrated)
 - One high-power channel for transmission, seven coaxial RF channels
 - 105 slip rings (16 for 400 Hz power, 89 for radar and nonradar signal paths)
- **Microwave Receiver**
 - Three channels, one of which is redundant
 - Each channel contains a receiver protector (RP) and a Low-Noise Amplifier (LNA)
 - RP has five stages to protect LNAs at various power levels; completely passive operation
 - High Electron Mobility Transistor (HEMT) LNAs provide low noise figure for maximum signal-to-noise reception of target signals

Transmitter Group

- **Transmit Electronics**
 - Predriver: 2 redundant solid-state low power amplifiers, 2 watts minimum peak power each
 - Transmit Angle Control (TAC): 2 redundant digitally controlled attenuators
 - Driver: 2 redundant medium power amplifiers
- **Klystron Power Amplifiers (KPAs)**
 - Two high power KPAs, two pulsers and grid pulser circuits
 - Pulser excursion: 1,000 V to +3,100 V
- **High Voltage Power Supply**
 - SF₆-pressurized units to reduce size and weight
 - 90 kV transformer, filter, and regulators
 - Comprises 5 of 21 major transmitter units
- **Auxiliary Units**
 - Protection sensors; power distribution and control circuits
 - Comprises 10 of 21 major transmitter units
 - Added filter for improved stability

Maritime Cabinet

- **Maritime Receiver**
 - Delay line pulse compressor, sensitivity time control circuits, envelope detector, CFAR circuits, A/D converter, microprocessor
 - Five Intermediate Frequency (IF) assemblies
- **Digital Land Mass Blanker (DLMB)**
 - Map storage memory, microcontroller
 - Digital control circuits

Engineered for Excellence

Excellence in design, engineering and manufacturing have created this sophisticated and powerful radar system. The functional subsystems that comprise the radar are described here and numerically correlated with the block diagram on the facing page.

1 Transmitter

• Transmit Electronics

- Predrivers – initial amplification of the signal from the STALO.
- Transmit angle control (TAC) – controls transmitted power vs. elevation angle.
- Drivers – intermediate power amplification.
- Pulser – provides pulses to KPA.
- Klystron Power Amplifiers (KPAs) – amplify and pulse-modulate RF signals; provide high peak power output over bandwidth.

• HV Power Supply

- Converts input prime power into filtered high voltage power.

• Auxiliary Units

- Distribute power to units and subassemblies.
- Provide protection for high voltage components and circuits.
- Control interrelated operation of 21 major units.

2 Array and Rotodome Equipment

• Antenna Array

- The antenna, composed of slotted waveguide radiators, provides a narrow beam with low sidelobes through amplitude tapering.

• Transmit Manifold

- Accepts transmitter RF output and delivers it to 28 amplitude-weighted radiating waveguides.

• Receive Manifold

- Accepts inputs from the 28 beam offset phase shifters, combines the signals in a power divider, and delivers the resultant signal to the microwave receiver.

• Beam Steering Phase Shifters

- Provide proper phasing of transmitted signals for low sidelobes.
- Provide phase shifts to 28 radiating elements for vertical beam scanning.
- Outputs of Beam Steering phase shifters on receive are delivered to the beam offset phase shifters.

• Beam Offset Phase Shifters

- Provide offset of receive beam from transmit beam during elevation scanning to compensate for time delay between transmit and receive of long-range aircraft returns.
- Provide space coincidence of receive and transmit beams in nonscanning modes.

• Phase Shifter Control Unit (PSCU)

- Accepts commands from the radar computer to stabilize or scan the beam.
- Accepts commands to select appropriate scan rate or squint angle.

• Phase Shifter Drive Unit (PSDU)

- Provides currents to drive beam steering phase shifters for beam stabilization and scanning and currents to drive beam offset phase shifters.

• Microwave Receiver

- Provides low-noise amplification of received signals.
- Provides receiver from high RF power of radar transmitter output or other sources.

• Rotary Coupler

- Provides the coupling of the RF and other signals into and from the rotating rotodome.

3 Analog Cabinet

• Analog Receiver

- Separates and routes Pulse Doppler (PD), Beyond-The-Horizon (BTH), and Maritime into separate receiver channels.
- Coherently detects PD signals in in-phase and quadrature channels.
- Provides clutter tracking for Pulse Doppler operation.
- Range gates PD signals and converts from analog to digital format; forwards to adaptive signal processor (ASP).
- Compresses, detects, and applies Constant False Alarm Rate (CFAR) to BTH pulses.
- Converts BTH data to digital format and outputs to Radar Interface Adapter Unit (RIAU).

• Radar Synchronizer

- Generates all timing signals to operate the radar.
- Provides software-controlled, selectable pulse repetition frequencies (PRFs).

• Stable Local Oscillator (STALO)

- Generates extremely stable radio frequency (RF) signals for radar transmission and signal conversion for detection processing.
- Provides basic clock for radar operation.
- Generates linear and non-linear FM signals.

4 Maritime Cabinet (AN/APY-2 only)

- Compresses, envelope detects, and converts maritime analog signal to digital data.
- Sets detection criteria based on CFAR optimized for sea clutter.
- Outputs maritime data in digital format to RIAU.
- Digital Land Mass Blanker (DLMB) prevents land returns from interfering with processing of maritime returns by use of stored digitized land maps.

5 Surveillance Radar Computer (SRC)

• Radar Interface Adapter Unit (RIAU)

- Interfaces the RDP to the ASP, RCMP and other radar units, the E-3 central computer, and instrumentation equipment through specialized input/output hardware.
- Includes two standard IEEE-488 interfaces to the RCMP.

• Adaptive Signal Processor (ASP)

- Performs digital pulse compression.
- Notches out mainbeam clutter signals for Pulse Doppler (PD) modes.
- Scans matrixed data and compares with dynamic thresholds for CFAR detection of signals.
- Outputs digital detection data to the Radar Data Processor (RDP).

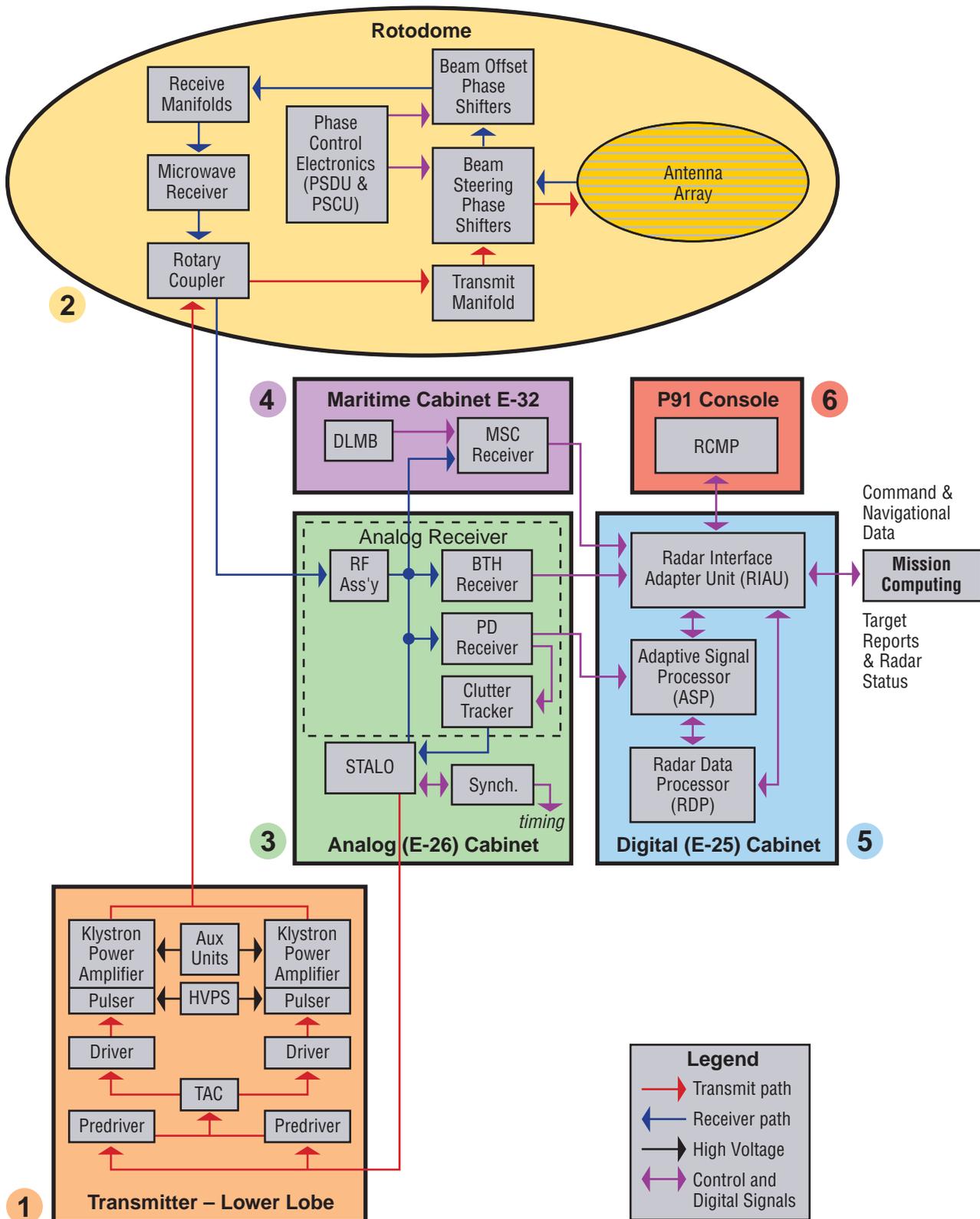
• Radar Data Processor (RDP)

- Accepts commands and input from central mission computer and RCMP via the RIAU.
- Receives and processes target data from the ASP, analog receiver, and maritime processor via the RIAU.
- Provides target and equipment status data to E-3 central computer and RCMP via the RIAU.
- Controls all radar internal operations including radar built-in test/fault isolation test (BIT/FIT).
- Controls RCMP user interface.
- Provides record/playback of radar data.

6 Radar Control and Maintenance Panel (RCMP)

- Turns radar on and off.
- Displays status and maintenance data.
- Controls radar during maintenance operation.
- Provides technician interface during maintenance testing and manual fault isolation.
- Has spectrum analyzer for ECCM features and special testing.
- Provides Fast Fourier Transform (FFT) and Plan Position Indicator (PPI) display.

Radar Block Diagram



Built for Reliability



Our expertise allows us to reach outstanding service benchmarks and keeps the aircraft operational

Radar system reliability and sustainability improvements are key to improving the availability and force-multiplying effects of AWACS. To ensure these improvements are rapidly incorporated into the radar system, Northrop Grumman Electronic Systems successfully merged design, manufacturing, and support capabilities into a world class Radar Support Center of Excellence (COE). The Radar Support Center of Excellence is a global network aimed at providing cost effective support and incremental system upgrades by inserting leading edge logistics and systems technologies. This coupled with the application of "best practices" enables the Radar Support Center of Excellence to efficiently handle all areas of logistics support while providing best value to the customer.

Logistics Engineering Services

The AWACS radar requires disciplined logistics planning and maintenance support to ensure effective day-to-day operations. Northrop Grumman Electronic Systems is experienced in supportability planning and can provide the strategic view essential for long term product sustainment. Our logistics engineers, design engineers, and field engineers collaborate to ensure that field data and customer feedback are considered throughout the

planning and implementation process. This team applies advanced analysis and modeling techniques to ensure cost effective support.

Depot Repair and Software Maintenance Services

Northrop Grumman Electronic Systems has a full range of repair and software maintenance capabilities integrated with the factory and our regional support centers. These comprehensive, seamless capabilities allow us to address all customer repair needs and to cost effectively insert performance and reliability upgrades to system hardware and software.

Field Engineering Services

An integral part of AWACS radar support are the services and on-site consultations provided by our Field Engineers. Our Field Engineers are actively involved in system development, integration, installation and checkout, acceptance testing, consulting, and other services required by our domestic and international customers. They are experienced at dealing with all levels of hardware/software operations and maintenance.

Technical Data and Advanced Diagnostic Systems

Northrop Grumman Electronic Systems provides the necessary technical data and diagnostic systems required to properly

maintain the AN/APY-1/2 radar systems. Operations/Maintenance manuals and software documentation can be delivered via print, electronic media, web based access or by embedding in mission or system test equipment. Also, advanced Standalone Diagnostic systems are available to enhance BIT/FIT diagnostics and analysis.

Training

The Radar Support Center of Excellence has the necessary tools and techniques to provide our customers with the proper training to operate and maintain the AWACS radar systems. Training engineers use simulations, scenarios and other techniques to teach theory, operations and maintenance.

Support Chain Management

Northrop Grumman Electronic Systems remains committed and capable of providing spare parts, assemblies and subsystems necessary to maintain the AWACS radar systems. Our eBusiness and Support Chain Management systems together with our innovative processes provide our customers with on-line part visibility and rapid resupply of spares and repairs.



ES provides world-wide AWACS support

Moving into the Future



21st Century AWACS Requirements

Better Performance

- Smaller Targets
- Greater Range
- Better Height Accuracy
- Improved Track Quality

Sustainment

- Lower Ownership Costs
- Improved Reliability & Maintainability

New Capabilities

- Slower Targets
- Helicopter Detection
- High Speed Missiles
- Frequency Diversity

Improving Surveillance to Meet 21st Century Needs

The Airborne Early Warning and Control (AEW&C) capability that AWACS provides has become an indispensable element of modern air operations. The strategic and tactical value of AWACS has grown over the decades since its initial deployment in the late 1970s, and will continue well into the 21st century.

As the world changes, the roles and missions of AWACS evolve. 21st century AEW&C missions are increasingly complex. In addition to its original AEW missions, AWACS is essential to a broad variety of operations, including Peace Support Operations, multi-national coalitions, air control, Homeland Defense, counter-narcotics, Combat Search and Rescue, and more.

The complex mission environment includes an airspace filled with a broader variety of air vehicles than ever before, including friendly forces, hostile forces, neutral and commercial aircraft, UAVs, and unknowns. Threats have multiplied and become more advanced, requiring

new capabilities to detect, track, and identify smaller targets, unmanned air vehicles, various missiles, and helicopters, in order to maintain situational awareness and ensure air superiority.

The E-3 AWACS is considered the most capable airborne surveillance system in the world. It was designed to meet specific goals and has been optimized to perform its task extremely well. However, advances in technology have made further radar improvements possible. Future modifications will allow AWACS to adapt to evolving missions and threats.

System upgrades are being studied or developed to provide:

- Improved detection performance
- Better track quality through processing techniques
- Detection and tracking of an expanded variety of target types, including slow or maneuvering targets, helicopters, and high speed targets such as missiles

- Greater frequency flexibility to operate effectively in the presence of electromagnetic interference
- Improved user interface
- Improved system reliability, maintainability, and availability (RMA)

Modernization and sustainment will ensure that AWACS continues to protect the skies with confidence well into the future.



NORTHROP GRUMMAN
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