

# **Aerospace System Improvements Enabled By Modern Phased Array Radar**

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## **ABSTRACT**

Modern Command, Control, Communications, and Computers Intelligence, Surveillance and Reconnaissance (C4ISR) Systems are providing unprecedented advances in national defence capability. The paper discusses the contribution that modern phased array radar enables in C4ISR aerospace systems and their role in network centric operations.

Phased array radar advancements for aerospace platforms are reviewed from a historical and technology viewpoint. The operational considerations that are unique to modern phased array radar are discussed along with their impact in optimising system effectiveness and their contribution in developing the Common Tactical Picture for integrated air and ground operations.

## **ABOUT THE AUTHOR:**

Robert Hendrix (Bob) is Chief Engineer for Northrop Grumman Electronic Systems Airborne Surveillance Systems in Baltimore Maryland. Northrop Grumman is a leading supplier of modern C4ISR systems including platforms, sensors, systems, and architectures for AWACS, JSTARS, 737 AEW&C, Global Hawk, F22 and Joint Strike Fighter. Mr. Hendrix joined what was the Westinghouse Electric Defence Electronics in 1962 as an Electrical Engineer. He has worked in electrical design and systems engineering on airborne, surface, and subsurface radar systems within the company since that time. Mr. Hendrix earned his Bachelor of Science degree in Electrical Engineering from the University of Maryland in 1963, his Masters of Science in Electrical Engineering from the University of Pittsburgh in 1968, and continued postgraduate work at the University of Maryland and George Washington University. He is currently developing modern C4ISR systems.

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# Aerospace System Improvements Enabled By Modern Phased Array Radar

## 1. INTRODUCTION

Phased array radar advancement has led to unprecedented advances in aerospace platforms and to national defence capability. Phased array radar for airborne platforms is reviewed from a historical and technology viewpoint. Then operational capabilities enabled by phased array radar are discussed for several key platforms. Finally, the use of phased arrays to develop a Common Tactical Picture of air and ground targets is discussed.

## 2. PHASED ARRAY RADAR SYSTEMS

The systems that are addressed here are systems in which Northrop Grumman Electronic Systems (ES) have been involved. Northrop Grumman ES, headquartered in Baltimore, Maryland USA, is a world leader in the design, development and manufacture of defence electronics and systems, precision weapons, airspace management systems, space systems, marine systems, and automation and information systems. Since World War II Northrop Grumman has delivered over 50,000 airborne radars, and is currently providing airborne radars on 21 aircraft types in 26 Nations.

Northrop Grumman ES has been designing and perfecting airborne radar systems for over 60 years, however the heritage of the phased array radar and particularly, Active Electronically Scanned Array (AESA) is relatively short. In fact, our first passive phased array radar was constructed in 1974 and the first active phased array was built just 17 years ago in 1985. This breakthrough in technology allowed for the demonstration of the concept of steering beams generated by distributed transmit and receive modules.

Our 2nd generation AESA was the first to fly just three years later. This 2nd generation AESA was the first AESA to proceed to the Engineering and Manufacturing Development phase. Our 3rd generation AESA met the high performance requirements in clutter, which mechanical or passive electronically scanned arrays are unable to meet. With the high performance standard set, we focused on reducing cost and weight.

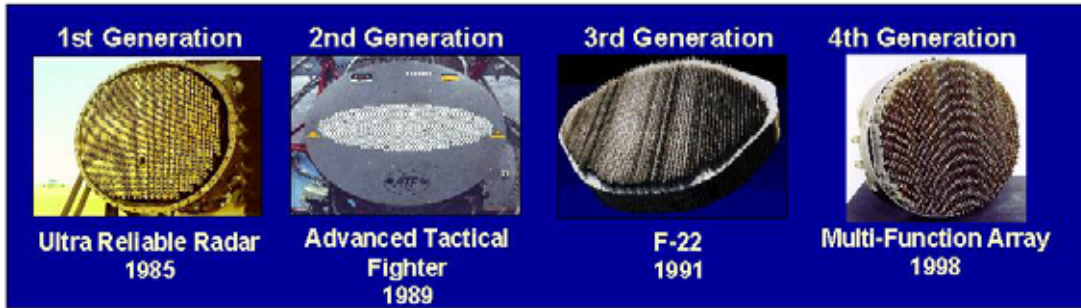
This led to our 4th generation AESA that is half the cost and weight of the 3rd generation AESA. The 4th generation AESA design requirements were the result of merging requirements for airborne, sea based, and land based platforms. Due to the nature of the changing defense environment dictating commonality across the services and our own limited research and development funds, drives one to the practical decision of seeking common solutions. This 4th generation AESA and its associated T/R modules achieve the design commonality while satisfying unique airborne, sea borne and ground based platform requirements with high performance to meet the mission needs.

The first generation airborne surveillance radar array was the Airborne Warning And Control System (AWACS) Brassboard radar antenna system. This antenna employed passive phased shifters on each of 28 sticks of the antenna, which were used to electronically scan the antenna to obtain height measurement and stabilize the beam to compensate for aircraft roll and pitch.

### 2.1 Electronically Scanned Array (ESA) Timeline:

Northrop Grumman ES is a world-leading producer of active aperture antennas. Figure 1.1 shows the evolution of our fire control radar active aperture development programs beginning with the 1st generation active aperture antenna in 1985 and covering up to our 5th generation multi-function array in 1998. The 4th generation active aperture (F-22) antenna is completing an EMD development

phase and moving towards production. The 5<sup>th</sup> generation active aperture antenna has completed initial development and is being leveraged into emerging development programs such as JSF.



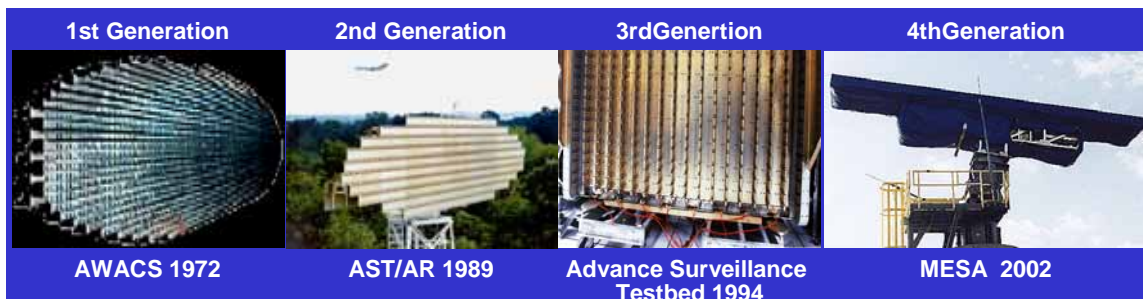
**Figure 2.1-1. Airborne Fire Control Radar Active Aperture Development**

Current development efforts are focused on the 5<sup>th</sup> generation antenna development. Architectures are being investigated for the sixth generation active aperture as well, and key technologies are being identified and developed. Key programs included in the roadmap include the development of a Ka-band tile and the Reconfigurable Array (RECAP). The Ka-band development effort has strategic significance to ES in the areas of radar as well as SATCOM.

**Airborne Fire Control Radar Active Aperture Development**

- 1974 – First development stages of EAR
- 1977 – EAR Flight-tested
- 1985 – URR First active aperture (1<sup>st</sup> Generation)
- 1988 – First to fly (2<sup>nd</sup> Generation)
- 1989 – ATF Concept Definition Phase for F-22
- 1991 – Awarded F-22 Contract
- 1995 – First to E&MD (3<sup>rd</sup> Generation)
  - Six units in test
  - High performance in clutter
- 1997 – Range tested APG-77 (4<sup>th</sup> Generation)
- 1998 – Launched 4<sup>th</sup> Generation AESA

**Airborne Surveillance Radar Active Aperture Development**



**Figure 2.1-2. Airborne Surveillance Radar Phased Array Development**

- 1970 – First ultra low sidelobe phased array developed
- 1972 – Phased array AWACS Brassboard radar system flight tested
- 1974 – Full Scale Development of AWACS
- 1982 – Development of JSTARS radar system (Norden Systems)
- 1989 – First ultra low sidelobe active phased array developed (AST/AR)
- 1994 – Flight test of Advanced Airborne Surveillance Testbed Radar (MCARM)
- 1998 – Prototypes of Multirole Electronically Scanned Array Radar/IFF
- 2000 – Award of 737 AEW&C MESA Radar Contract
- 2002 – First Full Scale MESA Radar/IFF Antenna

## 2.2 Product/System Overviews:

The EAR program was the development test bed for the future APQ-164 B-1B radar system. The system was the first ever, passive element phased array with a beam steering controller and a real time processor that allowed simultaneous Scanning Aperture Radar (SAR) and Terrain Following (TF) imagery. The system was first flown on a B-52 in 1977. The HELRATS system was used to simultaneously track two missiles and then feed the signal via fiber-optic cable to a system that used the data for targeting.

B-1B was the first development and production installation of an ESA radar system, which permitted a shared radar aperture and timeline allowing one radar to perform both Automatic Terrain Following and navigation radar functions. Synthetic Aperture Radar (SAR) developed for 10-foot to 160-foot resolutions. Demonstrated low probability of intercept TF and UHR/SAR modes. Demonstrated GPS Relative Targeting System (RTS) through measurement of quadratic phase error.

The AN/APQ-164 radar is an advanced phased array fire control, navigation and weapon targeting radar for the B-1B aircraft. Selected line replaceable units are essentially common with the APG-68 used in the F-16 C/D. The system is comprised of: a two axis electrically scanned phased array antenna, a radar receiver transmitter, a programmable signal processor, dual mode transmitter and a video signal processor.



**Figure 2.2-1. Electronically Agile Radar (EAR) High Energy Laser Radar Aided Targeting System (HELRATS)**



**Figure 2.2-2. APQ-164 (B-1B)**

The APQ-164 provides the B-1B with a Monopulse Ground Map (MGM) for an all weather area navigation aid. It provides a precise all-weather automatic Terrain Following (TF) and Terrain Avoidance (TA) capability for the B-1B. The APQ-164 provides the B-1B with a high resolution Synthetic Aperture Radar (SAR) for navigation and targeting nuclear and strategic weapons in all weather conditions. The radar can be modified with a Multitarget Track (MTT) software mode for Advanced Medium Range Air-to-Air Missile (AMRAAM) deployment.



**Figure 2.2-3. APQ-164 Phased Array Antenna**

Points of Interest/Milestones:

- First production delivery was in 1984
- More than 120 systems delivered
- Highly regarded by B-1B combat crews for effectiveness and reliability

Technical Experiences and Features:

- Multi-mode interleaved system with large, 2-D passive ESA providing safe and robust Terrain Following (TF).
- LPI waveforms and power management provided very low intercepts while achieving accurate measurements with very low peak power levels.
- ESA Air-to-Ground Modes – All weather precision strike mode capability: Moving target algorithm development (Slow Ground Moving Target Indication/Track (GMTI/T), clutter cancellation, Monopulse height above target) for the direct attack of moving targets (endo and exo clutter) is operationally proven.

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 defense forces. Proven in wartime operations such as Desert Storm and Allied Force, as well as ongoing peacekeeping and humanitarian efforts, AWACS is the premier air battle command and control aircraft in the world today.



**Figure 2.2-4. AN/APY-1/APY-2: Airborne Early Warning and Control System (AWACS)**

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 APY-1 and APY-2 radar systems used on the E-3, ES has been a leader in the development of radar technology for airborne applications.

The AN/APY-1/-2 Surveillance Radar System provides the down look surveillance capability for the E-3 AWACS. AWACS is designed to detect and track both enemy and friendly aircraft throughout a large volume of airspace. The radar provides full, long-range surveillance of high or low flying aircraft during all kinds of weather and above all kinds of terrain. The AN/APY-1/-2 can look down from an altitude of 30,000 feet and scan ranges exceeding 245 miles (400 kilometers), assessing both enemy and friendly resources.

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Mounted atop a Boeing 707 in a rotating dome that revolves through 360 degrees every 10 seconds, the ES radar was confirmed as the superior design in a series of competitive flights in 1972. The first production system was delivered in 1977. This system is now in service with a number of nations and the North Atlantic Treaty Organization (NATO).

The antenna is composed of slotted waveguide radiators, high power precision phase shifters for elevation beam steering and electronics for driving and control of the phase shifters. The antenna beam may be electronically scanned in the vertical dimension to obtain altitude measurements of targets. The antenna features a very high gain narrow antenna beam with ultra low sidelobes that are essential for the ability of the radar to detect small aircraft in the presence of high ground, and weather clutter as well as jamming.

The radar receivers, processing, and maintenance console are located in the 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 high power transmitter with Klystron final amplifier is located in the aft cargo section of the aircraft.

Northrop Grumman's ES division is presently working under a production contract for the Radar System Improvement Program (RSIP) for the U.S. Air Force. In 2000 Northrop Grumman's ES Division completed delivery and retrofit of the RSIP modification to NATO and the United Kingdom.

#### Points of Interest/Milestones:

- First prototype flight test 1972
- First production delivery was in 1977
- More than 75 systems delivered

#### Technical Experiences and Features:

- 360<sup>0</sup> surveillance, 10 second scan
- Clutter-free detection and tracking of low-altitude targets
- Beyond the Horizon early warning and surveillance
- Maritime Detection
- Extreme resistance to electronic countermeasures (ECM)

The Joint Surveillance Target Attack Radar system (Joint STARS) is a joint Army and Air Force program, with the air force as the lead service. Joint STARS is a long-range standoff air-to-ground surveillance system that provides real-time surveillance of the battlefield and rear echelons. The system detects, identifies, and tracks enemy armor and vehicular traffic throughout an extremely large field of view (over 40,000 square kilometers) and provides their locations to Air Force and Army Commands.



**Figure 2.2-5. APY-3: Joint Surveillance Target Attack Radar System (Joint STARS)**

Northrop Grumman Integrated Systems (IS) is the prime contractor and Northrop Grumman ES is responsible for the radar sensor group. A full-scale development contract was awarded to Northrop Grumman in 1985. USAF full rate production was authorized in late 1996. Subsequent versions of this system will incorporate the Multi Platform Radar Technology Insertion Program (MPRTIP) radar in the Boeing 767 aircraft.

The Joint STARS radar detects fixed and moving targets over large ground areas utilizing advanced Synthetic Aperture Radar (SAR) and sophisticated interferometer techniques. The radar's antenna is a 24-ft long, side looking, phased array that is electronically scanned in azimuth and mechanically scanned in elevation.



**Figure 2.2-6. JSTARS Phased Array Antenna**

While many radar systems can provide high resolution SAR, the Joint STARS radar provides both high resolution SAR and Moving Target Indication (MTI) at ranges out to the radar horizon.

Points of Interest/Milestones:

- JSTARS was a key part of Desert Storm, flying a total of 49 combat sorties and supporting 100% of mission tasking.
- JSTARS monitored the Iraqi retreat, allowing allied fighters to block potential escape routes.
- JSTARS also made a significant contribution during peacekeeping operations in Bosnia thus illustrating JSTARS' mission utility.

The Global Hawk is an Unmanned Air Vehicle that provides real-time surveillance of the battlefield and rear echelons. Flying at altitudes in excess of 60 thousand feet, the UAV stays aloft in excess of 30 hours. A variety of payloads have been demonstrated to date including radar and electro-optical sensor packages. The platform has been pressed into action in Afghanistan and has provided timely images to support the war on terrorism.



**Figure 2.2-7. MPRTIP: Global Hawk UAV**

Northrop Grumman Integrated Systems (IS) is the prime contractor. The production configuration is expected to carry the MultiPlatform Radar Technology Insertion Program (MPRTIP) radar. This is a smaller aperture version of the active phased array radar for JSTARS and is capable of MTI and SAR at significant ranges from 60 thousand feet altitude.

Points of Interest/Milestones:

- Global Hawk has pioneered high altitude long endurance UAV surveillance in operations over Afghanistan.

Northrop Grumman ES is the prime contractor on the TESAR project. The program required an all-weather, SAR imaging radar payload and associated ground control station hardware for the Medium Altitude Endurance (MAE) Unmanned Aerial Vehicle (UAV). TESAR quickly transitioned from development to production and was operationally deployed in Bosnia two years after inception. Original SAR requirements included one-foot map resolution, map swath range of 4-10.4 km, map swath width of 800 m, and a payload weight of 175 lbs.



**Figure 2.2-8. ZPQ-1: Tactical Endurance Synthetic Aperture Radar (TESAR)**

TESAR has been 100 percent operational during missions and is delivering the data that it was contracted to provide. TESAR earned high marks for performance and reliability.

TESAR has flown more than 40 flights and over 200 hours in direct support of Operation Joint Endeavor. Not one flight has been cancelled due to TESAR failure.



**Figure 2.2-9. TESAR**

Technical Experiences and Features:

- Hardware Reuse – Hardware design heritage from the A-12 radar was used as point of departure for the TESAR design including the Electronically Scanned Array for receiver components.
- Mode Performance – Operational experience demonstrated Ultra High Resolution SAR/GMTI in Tazsar, Hungary (Bosnia: Joint Endeavor/Guard).
- COTS – A Mercury Computer System signal processor and DY-4 data processor supplied the COTS hardware.

The Block 60 F-16 represents an evolutionary step ahead of the current F-16 Block 50 aircraft.

The AN/APG-80 is designed with an electronically scanned array radar with both smaller target and electronic counter-counter measures capabilities.

An internal Forward-Looking Infrared (FLIR) targeting system replaces the pods in earlier aircraft. With state-of-the-art components and packaging technology, the Internal FLIR Targeting System (IFTS) incorporates an advanced multi-functional FLIR/laser system into the F-16 nose to improve lethality and survivability with lower weight and drag. The elimination of bulky pods also enhances stealthiness.



**Figure 2.2-10. AN/APG-80 (F-16 Block 60)**

Additionally there is an integrated electronic warfare suite with internal electronic countermeasures, advanced radar, an electronic warfare management system, and up to eight chaff/flare dispensers, as well as advanced friend or foe. The aircraft's advanced avionics suite has room available for future improvements. The Block 60's modular mission computer has a processing throughput of 12.5 million instructions per second and provides sensor and weapons integration.

Technical Experiences and Features:

- A/A Detection Range Improved
- High Resolution SAR for All Weather Precision Attack
- Integration with Advanced GPS Weapons
- Reduced Cost of Ownership through High Reliability Design
  - Predicted System MTBF of 390 hours
- Agile Beam Radar with Auto Terrain Follow
- Advanced ECCM

Northrop Grumman ES is responsible for the overall design of the AN/APG-77 radar system, including the control and signal processing software. Northrop Grumman also has responsibility for radar systems integration and test activities. The main component of the radar sensor is a highly reliable Active Electronically Scanned Array (AESA), which provides the rapid beam agility, low radar cross section and target detection capability that enables the air dominance fighter to achieve it "first look, first kill" capability.

Northrop Grumman's AN/APG-77 radar employs a different type of electronically scanned phased array. In what is likely to be the most advanced airborne radar in the world, individual transmit and receive modules will be located behind each element of the radar array. The transmit function of the solid-state microwave modules will supplant the travelling wave tubes used in prior radars like the APQ-164.

The AESA configuration will have a wider transmit bandwidth while requiring significantly less volume and prime power. The system represents about half the weight of an equivalent passive ESA design. Each of the hundreds of individual solid-state devices generates only small amounts of power, but the aggregate for the entire array will be substantial.

The APG-77's active aperture antenna offers attractive benefits. The system exhibits a very low radar cross section, supporting the F-22's stealthy design. Reliability of the all-solid-state system is expected to be substantially better than the already highly reliable F-16 radar, with MTBF predicted at more than 450 hours.

Technical Experiences and Features:

- Weapons System Integration – Integrated an LPI, AESA radar into a tactical avionics and weapons suite.
- Supportability – designed for two-level maintenance and high reliability (MTBF over 450 hours).

- All performance specifications have been met or exceeded.

Under a four-year contract with the U.S. Department of Defence (DoD) JSF program office, Northrop Grumman ES designed, developed and successfully flight-tested an AESA radar system for the JSF program. The project, officially known as the Multifunction Integrated RF System/Multifunction Array (MIRFS/MFA), was designed to assist the government and the JSF prime weapon system contractors in reducing cost and technical risks associated with the aircraft's radar system.



**Figure 2.2-13. Joint Strike Fighter: JSF**

The performance of the MIRFS/MFA radar during rooftop and flight demonstrations consistently exceeded expectations and clearly indicated that the ES AESA design meets JSF operational and support requirements. Since December 1998, a variety of operational radar modes have been successfully demonstrated in flight on the ES BAC 1-11 avionics test bed aircraft including air-to-air, synthetic aperture radar, ground moving target indication and active and passive electronic warfare.

The radar system features an advanced AESA antenna, a high-performance radar receiver/exciter and a commercial off-the-shelf processor. The system incorporates a number of AESA radar technology innovations, resulting in dramatic reductions in cost and weight while also providing significantly improved reliability and efficiency.

For example, costs have been significantly reduced through the development by Northrop Grumman engineers of unique, highly affordable transmit/receive (T/R) modules featuring significantly fewer parts and electronic interconnects compared with previous generations. Assembly of the AESA has been greatly simplified and includes an open system architecture that readily accommodates growth via the insertion of future technologies. During the MIRFS/MFA program, Northrop Grumman demonstrated the capability for 100 percent automated assembly of T/R modules with production-like yields. In addition, the T/R modules exhibited no failures and no degradation of performance during extensive independent environmental tests conducted at the U.S. Navy's labs at China Lake.

As a result, Northrop Grumman expects the reliability of its AESA radar to be an order of magnitude better than currently fielded mechanically scanned array radar systems, while reducing logistics footprint and overall support costs by greater than 50 percent.

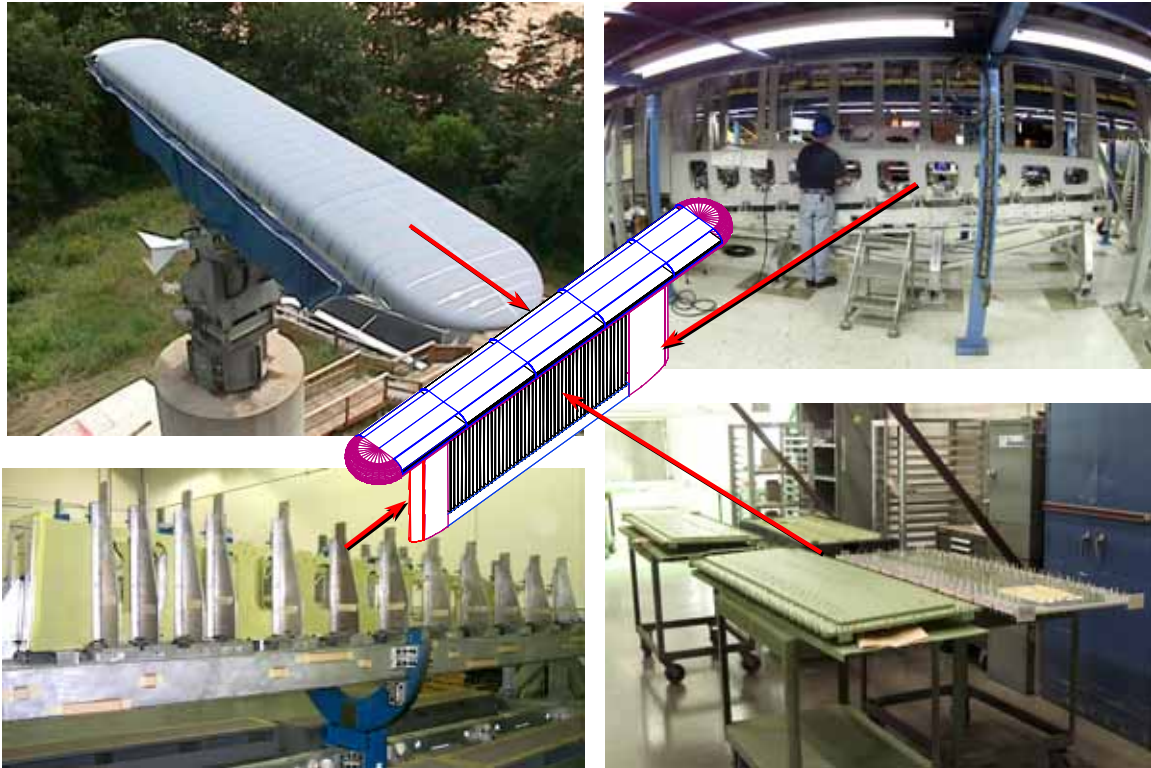
During the course of the MIRFS/MFA program, Northrop Grumman's JSF software engineering team earned the Software Engineering Institute (SEI) Level 4 software maturity rating. This places ES in the top 7 percent of all DoD and other Federal government contractor organizations when measured against SEI's stringent software development standards.

Advances in technology have caused a revolution in the capabilities and flexibility of airborne surveillance systems and sensors used in Airborne Early Warning & Control (AEW&C) systems. Developments in distributed transmitters, commercial off-the-shelf processing and high-performance antenna arrays have enabled ES multirole electronically scanned array (MESA) radar to be cost effectively applied to the next generation Boeing 737-700 series aircraft. The MESA radar provides air-to-air coverage, air-to-surface coverage, integrated identification friend or foe, special track beams and focused sector operation.



**Figure 2.2-14. Multi Role Electronically Scanned Array: MESA**

The ES MESA system leverages the experience from AWACS in an all-new radar design. The development of a state-of-the-art of Endfire ESA technology provides 360° coverage, without the utilization of a heavy rotodome. The MESA system is 3 ESA Arrays, integrated to provide 360° Coverage. Each side array provides  $\pm 60^\circ$  azimuth coverage port/starboard and the endfire “Top Hat” array provides  $\pm 30^\circ$  Coverage Fore and Aft.



**Figure 2.2-15. MESA Radar/IFF Phased Array Antenna**

Northrop Grumman ES has been advancing the ESA Array technology to provide a system that is High Gain, Electronically Scannable with low sidelobe performance.

MESA Radar/IFF statistics:

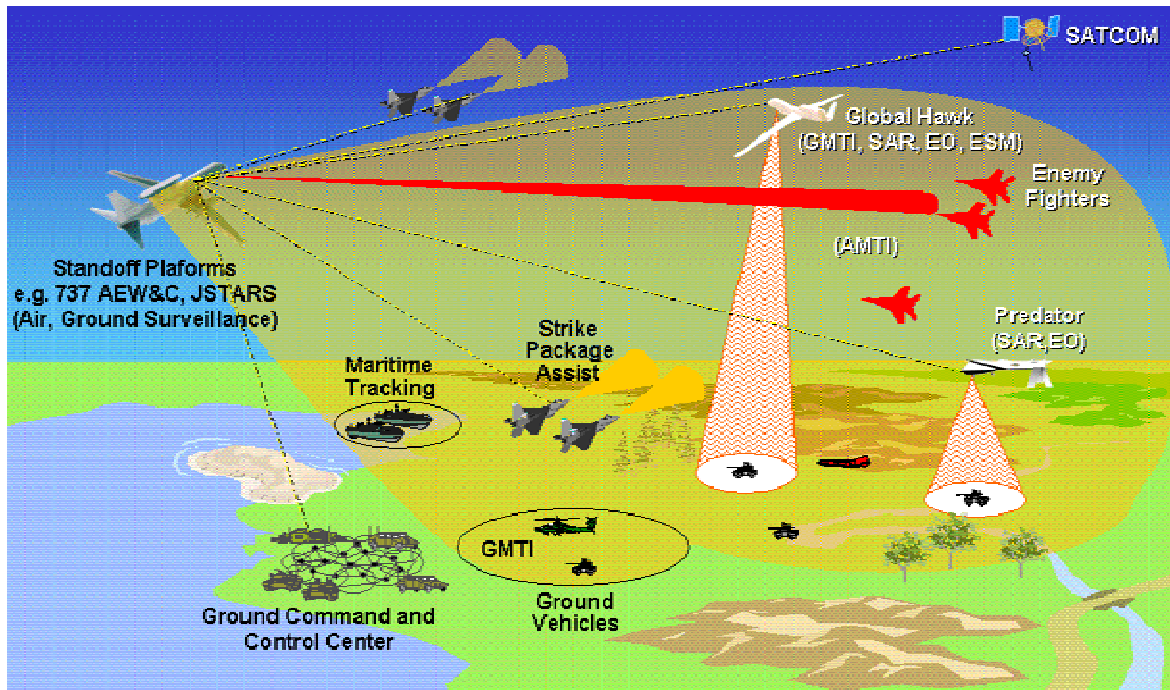
- Electronically steerable
- 360-degree surveillance coverage

- Interleaved air-to-air and maritime modes
- Long-range detection
- Dedicated track/high-update modes
- Integrated IFF
- COTS software and processors
- Lightweight, efficient aerodynamic design
- High reliability

### 3. OPERATIONAL CAPABILITY OF MODERN PHASED ARRAYS

The advent of mature phased array radar technology has changed national defence and the battlefield. The agility of the beam of a phased array radar is the key characteristic that has facilitated this change when coupled with the tremendous growth in computing power for processing information and presenting that data for decision making.

The modern battlefield, depicted in Figure 3-1, consists of advance airborne surveillance and fire control systems for conducting the air and ground operations. Phased array radars in these standoff platforms, fighters, and UAVs are key to successful conduct of the Air and Ground Battle.



**Figure 3-1. Advanced Airborne Surveillance and Fire Control Systems**

The improved picture provided by a standoff AEW platform carrying ESA phased array radar greatly enhances both defensive and offensive air operations. The ability to extend detection range in the direction of the threat, improve the tracking of threat targets, and stabilize the picture to the airborne controller with reference either to platform or geography simplifies the data picture. The use of underlay maps using a common grid allows the controller to easily define surveillance areas. Paths of ingress and egress are easy to identify. Coordination with anti-air systems is facilitated by the airborne ESA being the “eyes over the hill” for the targeting systems.

The improved picture provided by a standoff platform carrying ground surveillance ESA phased array radar greatly enhances the ground operations. The ability to present wide area, simultaneous MTI and SAR maps, enables situation assessment and ground battle execution by coordination of both air and ground forces. UAVs are cued to provide information over the battlefield from line of sights different from the standoff sensors to aid in unmasking targets hidden by mountains and hills. Higher altitude sensors of the Global Hawk class UAVs provide wide area information while remaining relatively out of harms way. Low altitude Predator class UAVs provide high quality information at closer range with phased array radar and E/O imaging sensors.

Likewise, manned fighters equipped with ESA phased array radars efficiently carry out their offensive and defensive missions aided by (and supporting) situation assessment from a netted picture from the multiple sensors viewing the battlefield. With the rapid revisit rates of an ESA and the focus on a specific axis, the chance of lost tracks and misplaced Blue assets diminishes greatly. The airborne ESA eliminates the shadows that impact ground control of outbound strike packages while providing coverage for those packages from airborne surprises that pop-up from one valley over. The interleaving of IFF with radar tracking greatly reduces Blue on Blue engagements. This extends to the interface with the air defence system for returning Blue assets as well.

The in-motion, remote from the FEBA standoff sensor, is harder to kill via sudden enemy strike. The tremendous range of the sector-search ESA protects against airborne attack by enemy air assets, while the lookdown eliminates shadows on the Blue side of the FEBA. By linking with the air defence system, low targets are easy to hand-off to Combat Air Patrol (CAP) aircraft or waiting batteries, and Blue on Blue engagement is minimized.

Data and voice links with ground C4I with the high data rates available now, allow the sending of entire radar pictures enhancing the situational awareness of air, land and sea forces at the tactical and strategic levels. The airborne position of the AEW eliminates the communications shadows, and provides relay capabilities to augment land systems.

By providing real-time MTI and SAR data to ground systems, the army sector commander can better utilize air and land assets to counter an attack, either by disrupting the assault before it is underway, or by taking active aggression in its weak spots. Similarly, maritime surveillance also benefits through ready identification of surface combatants in the littoral environment as well as the open ocean. Additionally, there is added peacetime benefits for shipping as well. The broad area of surveillance allows for remote support of a ship-in-distress, providing tracking of disabled ships, even including environmental spills, and the vectoring of air and sea assets for rescue.

The paragraphs which follow discuss the capability of large phased arrays on standoff platforms to detect air and ground targets. Then an approach for combined air and ground operations is discussed including the netting of platforms to develop a Common Tactical Picture for conducting operations against air and ground targets.

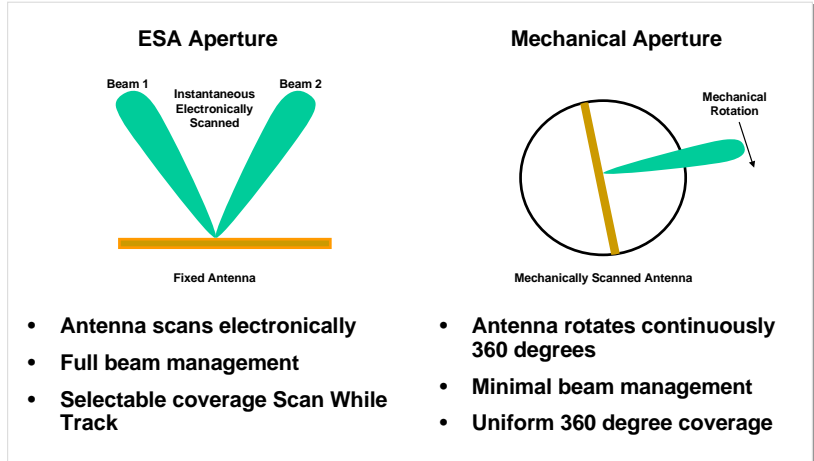
### **3.1 Coverage Of Air Targets From Standoff Platforms**

Radar detection of aircraft and missiles at long standoff range requires large, high power radars such as the 737 AEW&C MESA. The 737 AEW&C MESA is able to provide sectors of increased detection range rather than uniform detection range as in previous generation radar. The MESA electronic scanned antenna beam shown in Figure 3.1-1 enables the energy from the radar or IFF beam to move “instantaneously” to new beam positions. This instantaneous movement or “beam management” permits tailoring of the radar/IFF coverage to match the operational needs of the user. Continuous air surveillance can be accomplished simultaneously with other functions.

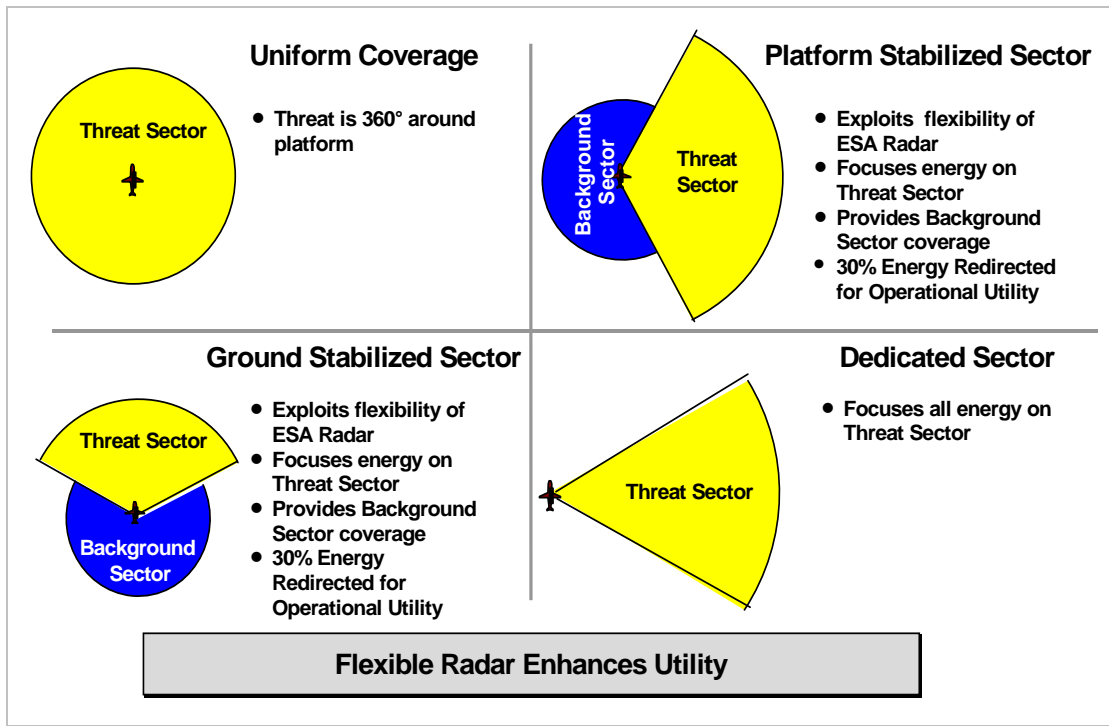
The flexibility of the MESA radar enables an operator to use it in virtually unlimited combinations of surveillance and tracking. Four typical surveillance combinations are shown in Figure 3.1-2.

In addition to the surveillance modes possible, MESA track beams can be employed to frequently revisit high priority tracks. High priority tracks can be targets involved in high-speed maneuvers, where the operator desires additional data on the target or when the tracker desires additional detections. The additional target detections provided by the Track Revisit mode would improve tracking.

Tracking can be optimised utilizing the Track Revisit mode, or for areas of interest additional radar resources (time) can be allocated to that area. By increasing the radar resources dedicated to a particular sector, the maximum detection range is extended. The additional resources increase the probability of detecting targets, thereby optimising the tracker's ability to track the targets.



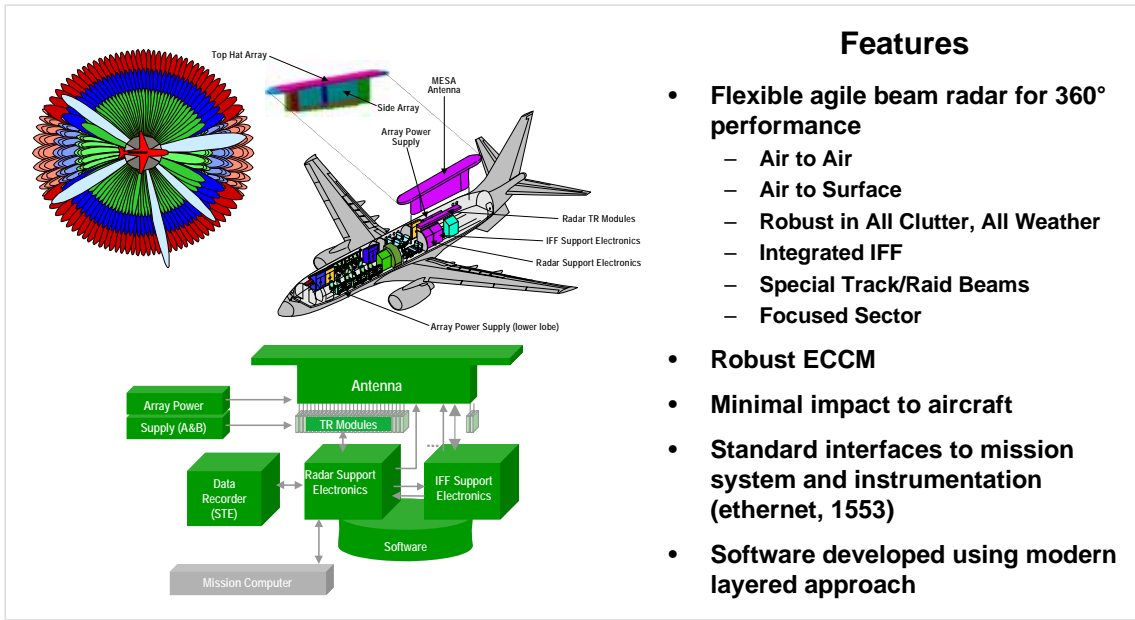
**Figure 3.1-1. The MESA electronic scanning of the antenna beam enables the energy from the radar or IFF beam to move “instantaneously” to new beam positions**



**Figure 3.1-2. Four Representative Air Surveillance Combinations For 737 AEW&C**

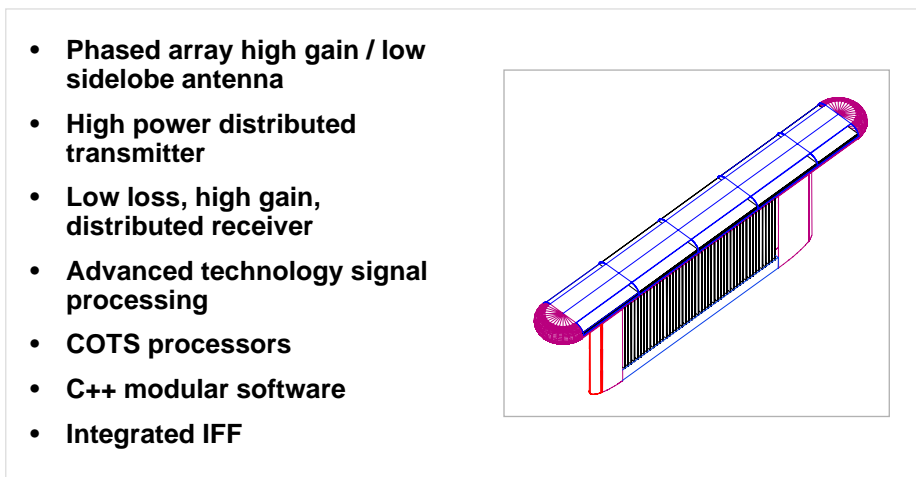
A summary description of the MESA Radar/IFF is given in Figure 3.1-3. The radar provides air-to-air coverage, air to surface coverage, integrated IFF, special track/raid beams, and focused sector operation. It is designed with a modular open system architecture using standard interfaces. The software is constructed using a modern layered approach. The hardware is composed of five major

subsystems: Antenna, T/R Modules, Array Power Supply, Radar Support Electronics, and IFF Support Electronics.



**Figure 3.1-3. MESA Phased Array Radar/IFF System**

The MESA radar is designed for lightweight and to minimize aircraft impact. The radar antenna shown in Figure 3.1-4 is composed of three apertures: two back to back dorsal arrays provide 120 degrees of azimuth coverage on each side of the aircraft, and a top hat array provides 60 degrees of azimuth coverage forward and aft of the aircraft. The antenna shape minimizes the drag and aerodynamic impact on the airplane and lightweight technology is used to minimize weight and impact on time on station



**Figure 3.1-4. MESA Phased Array Antenna – Three Separate Faces Arranged in Aerodynamic Design**

### 3.2 Coverage of Ground Targets From Standoff Platforms

Radar detection of ground targets at long standoff range also requires the use of large phased arrays such as JSTARS or the 737 AEW&C. Large aperture phased array beam flexibility enables coverage of the ground using both Moving Target Indicator (MTI) radar and Synthetic Aperture Radar (SAR). As in the case of Air Target coverage discussed above, the instantaneous movement of the phased array beam permits tailoring of coverage. MTI and SAR images can be obtained for areas of interest and overlaid to examine both fixed and moving surface targets and to conduct military operations against ground targets as illustrated in Figure 3.2-1.

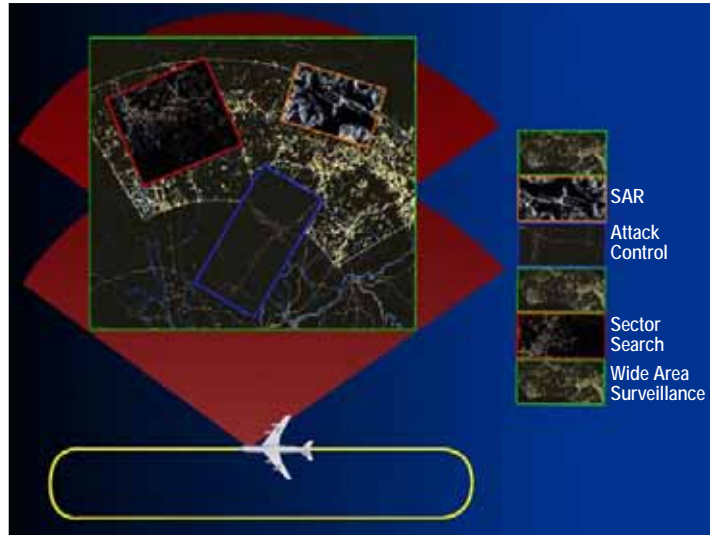


Figure 3.2-1. Ground Coverage

### 3.3 Combined Tactical Picture

The combination of air and surface coverage from a single platform or netted platforms leads to a Combined Tactical Picture. The combined picture enables mission operators to assess the tactical situation and conduct both counter air and counter ground operations.

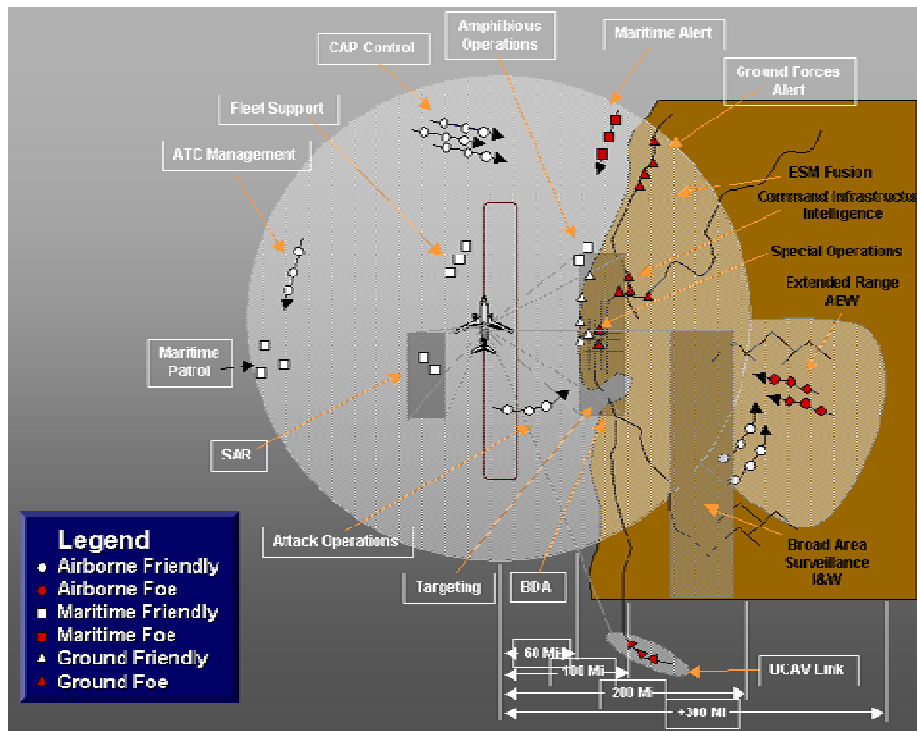
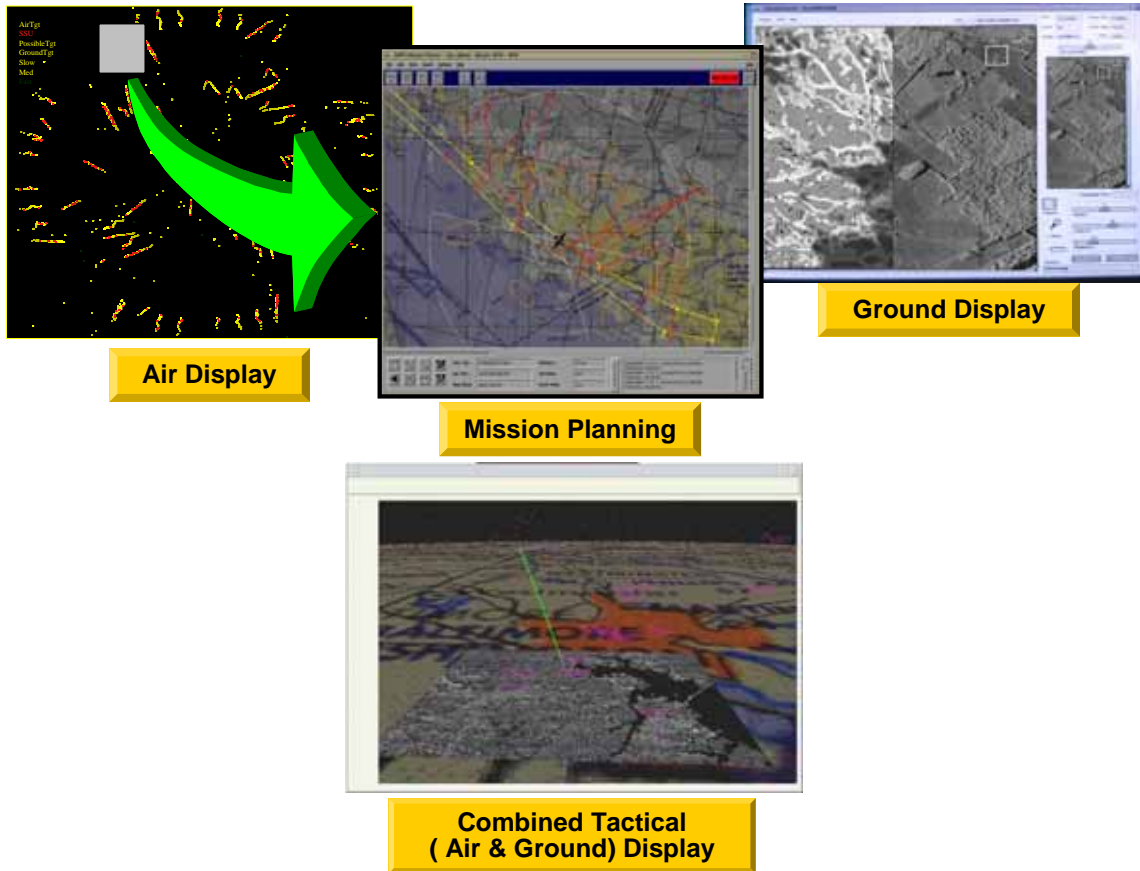


Figure 3.3-1. Integrated Operations

Future battlefield will include unmanned air, sea, and land sensors, both mobile and stationary. The airborne platform is ideally positioned to provide tracking and command of these new elements. This includes sensors in lower interest areas, where radar tracking is not desired, but continued monitoring of the sensor platform is. The ability to data link instructions from the AEW platform and information from the ESA radar gives even greater effectiveness to these new automated tools of the military.



**Figure 3.3-2. Combined Tactical Picture Display**

#### 4. SUMMARY

Since the early 1980's Northrop Grumman's ES division has been responsible for the many technological advances in the field of radar technology and more specifically Electronically Scanned Phased Arrays. With major milestones such as the EAR and APQ-164, the ESA technology was established as the wave of the future. With the increasing role of airborne surveillance and warning, ESA technology has proven to be a key factor in establishing theatre superiority. Systems such as APY-1/2/3 (AWACS and JSTARS), ZPQ-1TESAR have proven their capabilities time and time again during Desert Storm, and Bosnia, Kosovo, and Afghanistan confrontations. The new generation of Active Electronically Scanned Phased Arrays are being incorporated into systems such as the F-22 Air Superiority fighter, the Joint Strike Fighter (JSF), F-16 Block-60 and now the Multirole Electronically Scanned Array (MESA) for the Boeing 737 AEW&C.

The new generation of phased array systems is enabling unprecedented capability in National Defence. Phased arrays are key to superior battle management and weapons delivery. The Common Tactical Picture is integral part of this capability.