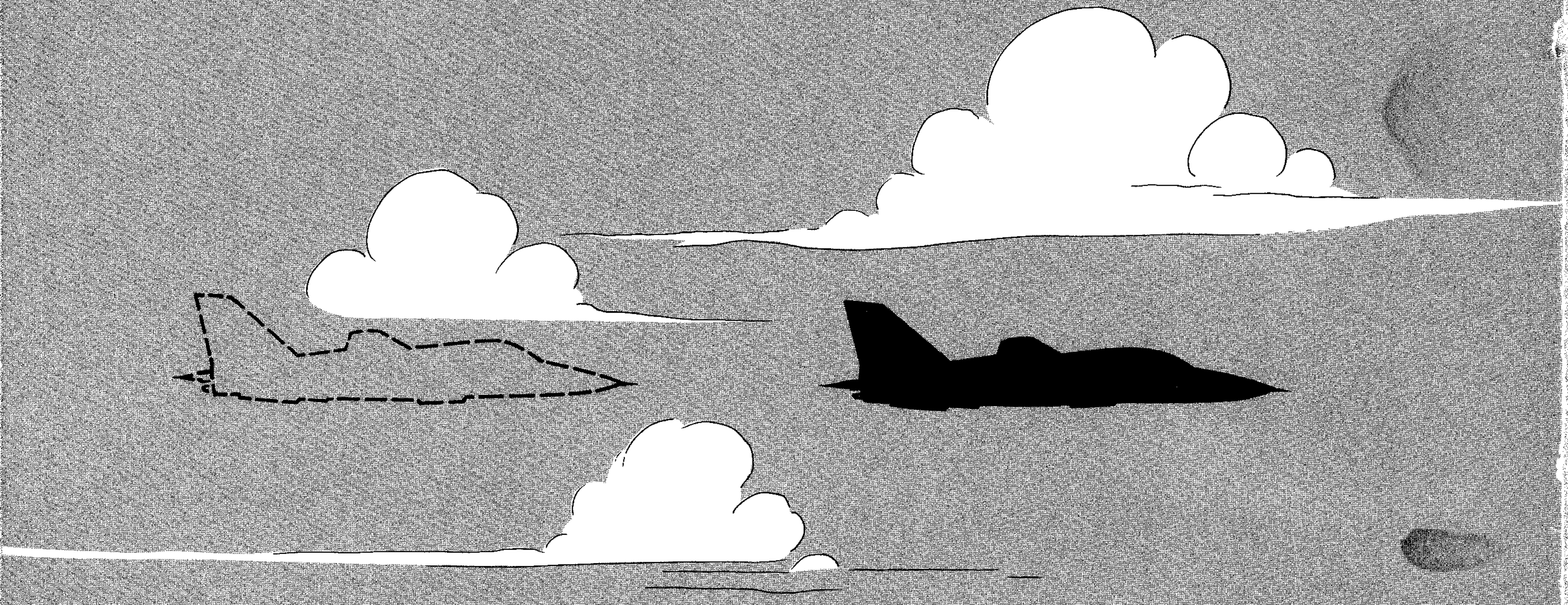
ELECTRONIC WARFARE

NAVELEX PROGRAM INFORMATION SERIES



NAVAL ELECTRONIC SYSTEMS COMMAND
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20360

ELECTRONIC WARFARE

The NAVELEX Program Information Series describes important segments of the Naval Electronic Systems Command's activity. This volume presents a brief history of electronic warfare, current Navy capabilities and NAVELEX plans for the development of electronic warfare systems. Since the details of electronic warfare operations and technical data on specific equipments are generally classified, descriptions in certain areas have been limited in detail in order that this publication may remain unclassified.

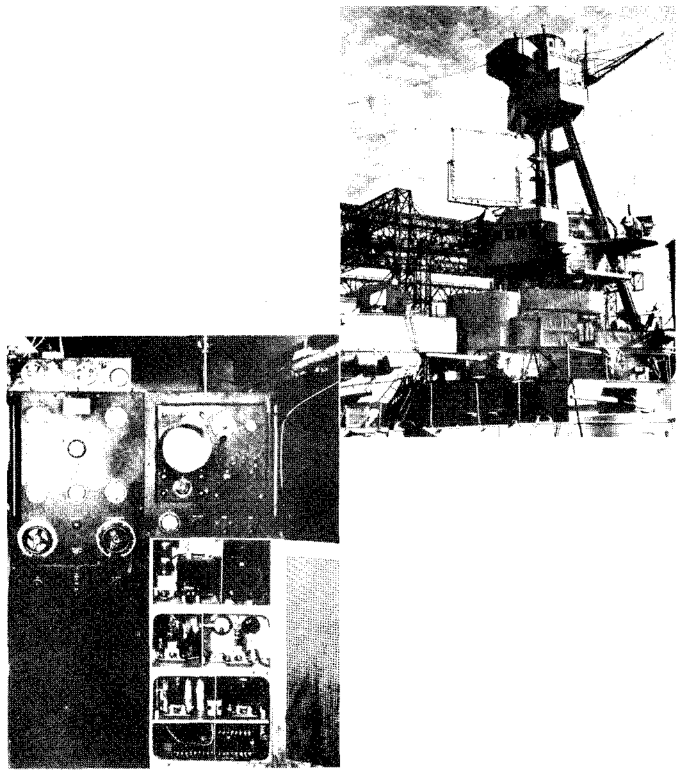
Electronic warfare encompasses the military action involved in using electromagnetic energy to determine, exploit, reduce or prevent the hostile use of the electromagnetic spectrum. The NAVELEX electronic warfare effort is principally the responsibility of the REWSON (Reconnaissance, Electronic Warfare, Special Operations, and Naval Intelligence Systems) Project Office (PME107). This office manages the development of ship and submarine electronic warfare systems, and, through PMA523, the development of airborne electronic warfare systems. Work is in progress on electro-optic sensors and countermeasures, electronic warfare support measures systems, and threat reactive systems. The REWSON Office manages the Design-to-Price Electronic Warfare System development, a new concept in naval warfare system acquisition in which contractors compete to provide the highest operational capability at fixed production prices. The REWSON Office also cooperates with the Naval Air Systems and Sea Systems Commands in the development of electronic warfare equipments for aircraft and ships, and maintains liaison with the Navy Intelligence Command to assist in collection efforts and to utilize intelligence information in equipment developments.

The Electronic and Special Warfare Division (ELEX 350) of the Research and Technology Directorate is responsible for exploratory development of the techniques and devices essential to the formulation of future EW systems. Their efforts are supported by the Technology Division (ELEX 304) in developing new component technology. Under NAVELEX direction field activities and laboratories also take an active role in EW system development and test and evaluation.

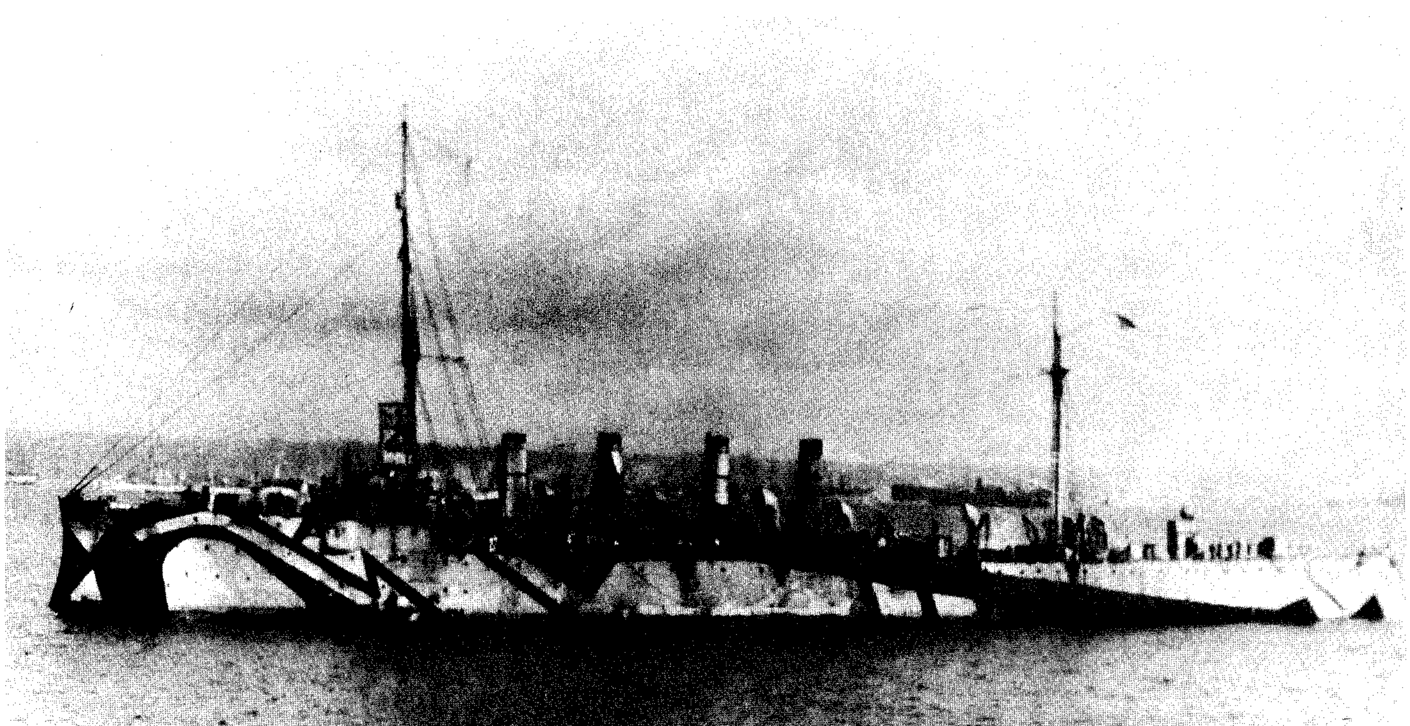
HISTORY OF ELECTRONIC WARFARE

Electronic warfare (EW) tactics, techniques and equipments capitalize on the fact that the radiation of electromagnetic energy is susceptible to detection, exploitation and interference. As the navies of the world increased their use of radio for communications in the early 1900's, techniques for the naval employment of electronic warfare came under study. Electronic warfare in World War I was concerned mainly with procedures for intercepting and exploiting enemy communications, and with the development of direction-finding equipment to locate enemy radio transmitters. Direction finders installed in destroyers proved to be effective in locating the positions of enemy submarines. The Navy also established direction-finding stations ashore, with wire communications to the flagship at Brest, where the bearings on submarine transmitters were combined to determine submarines' positions.

In the period between World War I and World War II, electronic equipment developments stressed improvements in radio receivers and transmitters, and electronic warfare techniques changed very little from those employed in World War I. The discovery of radar principles in 1922 set the stage for a whole new field of potential EW applications, but employment of electronic warfare in the Navy did not expand appreciably until the beginning of World War II.



XAF RADAR INSTALLATION IN USS NEW YORK, 1938



USS BIRMINGHAM (CL-2), FLAGSHIP OF U.S. FORCES, IN BREST, FRANCE, OCTOBER, 1918

ELECTRONIC WARFARE IN WORLD WAR II

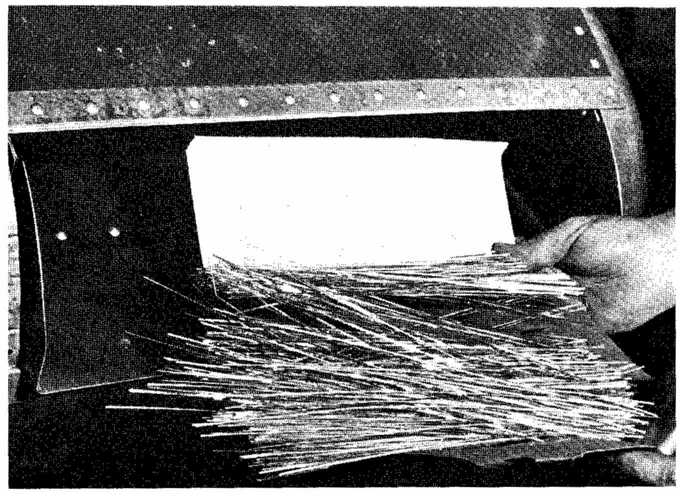
The great advances in electronic technology that took place before and during World War II were quickly applied to naval warfare. Electronic equipment was developed for the identification and recognition of ships and aircraft, for jamming enemy radar and communications systems and disrupting electronic control systems, and for counteracting enemy measures to jam our equipment. The effectiveness of direction-finding equipment was also improved by implementing the capability to cover higher communications and radar frequencies, and by refining its precision and accuracy. In some representative electronic warfare actions that occurred during World War II:

- *Luftwaffe* bombers equipped with special direction-finding antennas rode beams generated by German short wave radio stations to guide them on raids against cities in England. To counter this tactic, British "beaconing" (deception) systems repeated the German navigation signals, thus confusing the German bomber crews.

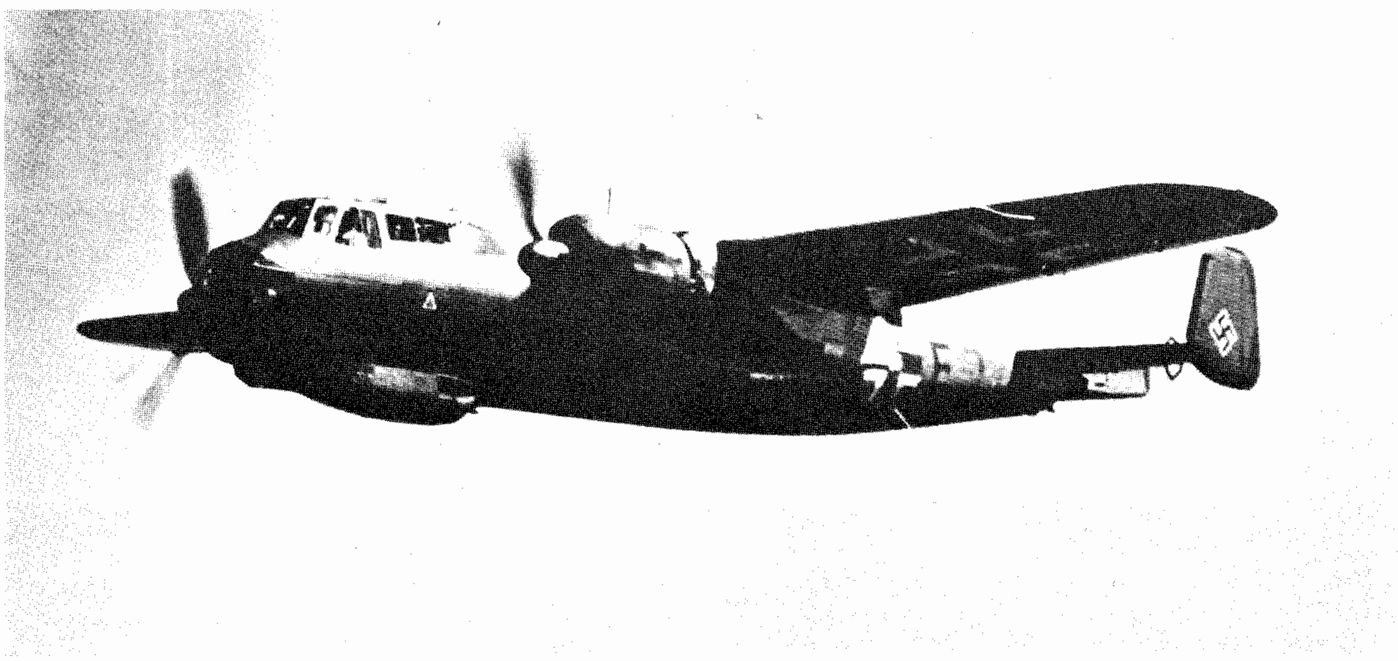
- A giant German *Wurzburg* radar, installed on the French coast, directed the fire of long-range coastal batteries against shipping in the English Channel. A force of British paratroopers conducted a raid on the site, capturing vital parts of the radar; information derived from a study of the captured equipment was used in developing jammers which greatly reduced the effectiveness of the *Wurzburg* system.

- U. S. strategic bombers in Europe were equipped with noise jammers having a power output of about 5 watts, to protect them from anti-aircraft fire controlled by German gun-laying radars. In a raid against Bremen in October, 1943, two groups of bombers equipped with the jammers experienced less than half the losses suffered by planes not similarly protected.

- Both sides employed a very effective passive means of confusing enemy radar in order to protect their aircraft. Aluminum foil, cut into strips of about one-half the wavelength of the enemy radar frequency, was dropped from aircraft to present false echoes to enemy radars. The material was code named "window" by the British and *Dueppel* by the Germans, and is now called "chaff."

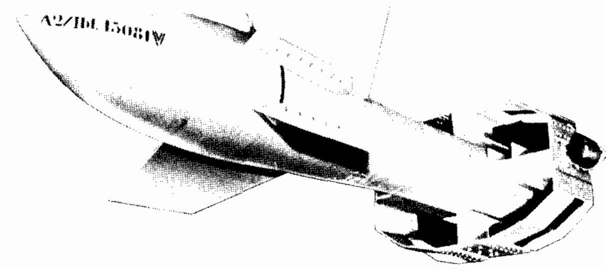


"WINDOW," USED TO CONFUSE ENEMY RADARS DURING BOMBING RAIDS OVER GERMANY

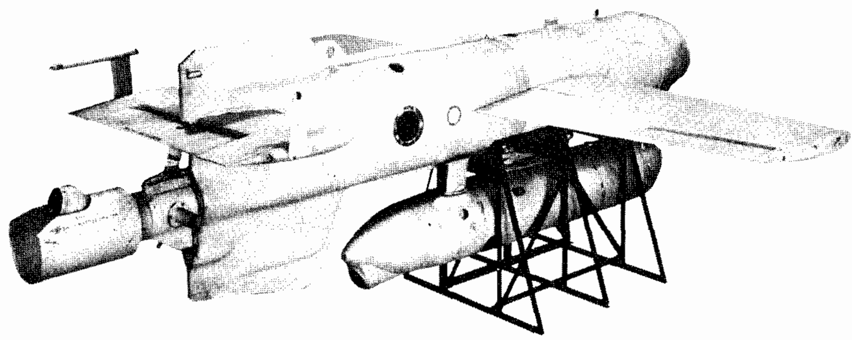


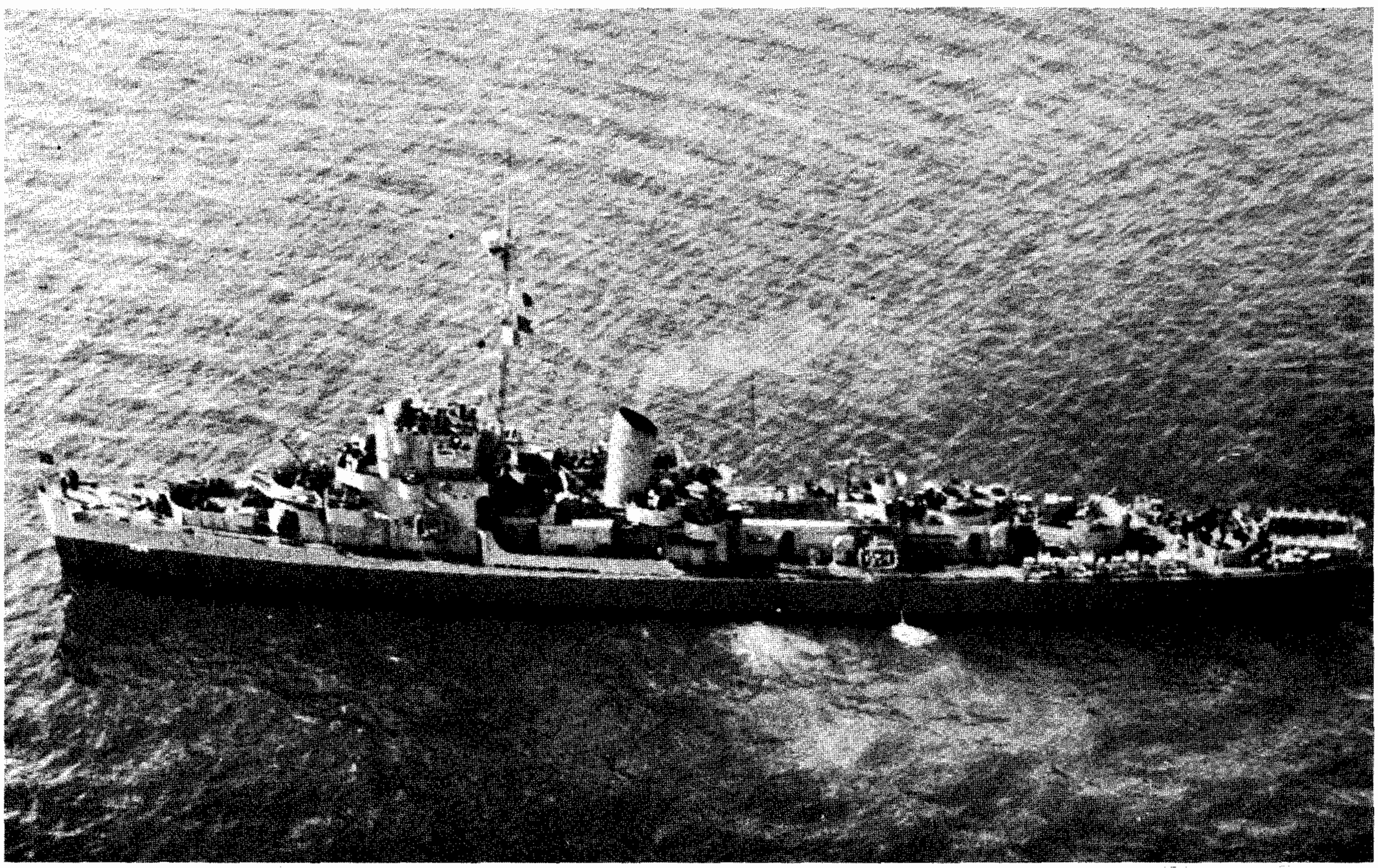
GERMAN DORNIER DO-217 BOMBER

● In 1943 the Germans put into operation two types of radio-controlled missiles which threatened to take a heavy toll of British and American shipping. They were jet-propelled, and after release from a mother plane which remained from three to ten miles from the target, were guided by radio command from the mother plane. Two U. S. destroyer escorts were quickly equipped with countermeasures systems developed by the Naval Research Laboratory and dispatched to the Mediterranean. At least ten German missiles were released against these two ships without one hit being scored; a crash program was then undertaken to equip destroyers in the Mediterranean with improved apparatus of the same type. This equipment proved to be so successful that no further hits were recorded on capital ships for the remainder of the war.



NAZI RADIO-CONTROLLED AIR-TO-GROUND BOMBS, USED EXTENSIVELY AGAINST SHIPPING





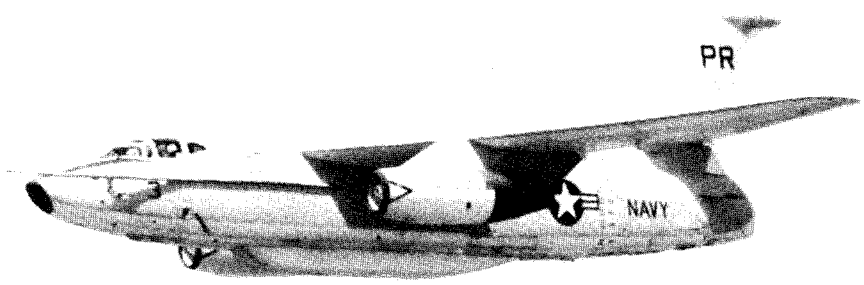
USS FREDERICK C. DAVIS (DE136), ONE OF THE DESTROYER ESCORTS EQUIPPED WITH COUNTERMEASURES SYSTEMS TO DEFEAT GERMAN RADIO-CONTROLLED BOMBS

POST WORLD WAR II DEVELOPMENTS

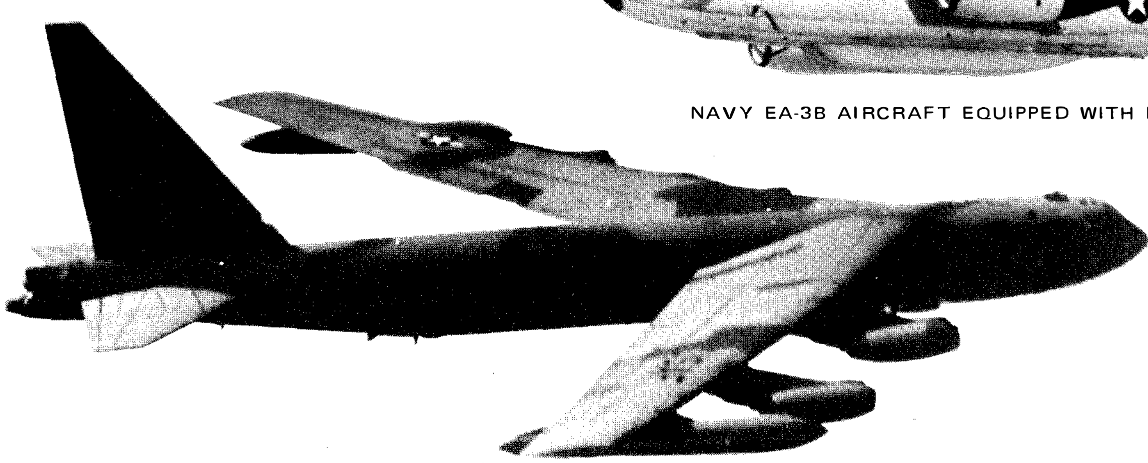
The current electronic warfare program for U. S. ships and aircraft has been largely shaped by cold war events in the 1950's and the Vietnam War. In response to cold war threats, countermeasures systems were installed in Strategic Air Command aircraft in the 1950's, and at a later date in the Navy's nuclear strike aircraft. The development of electronic countermeasures was fostered by an appreciation of the increased lethality of radar-directed gun and missile systems. The introduction of surface-to-air missiles (SAM's) into operational use by the North Vietnamese accelerated the development of countermeasures for tactical aircraft. A number of such countermeasures techniques were developed and employed, most of them directed toward increasing the survivability of aircraft over a target area. Airborne countermeasures of necessity progressed from planning to operational stages on a quick-reaction basis, driven by an urgent need to reduce combat losses from specific threats. The strategic-oriented programs of the 1950's provided the technological base for the accelerated development of countermeasures which were employed in Vietnam. The development of electronic warfare techniques and equipments for ships lagged behind those for aircraft because ships were not as likely to come under attack.

THE COLD WAR

Faced with the task of penetrating the formidable defensive network that the Soviets developed during the cold war period, Strategic Air Command (SAC) planners implemented advanced electronic warfare concepts to increase the probability of accomplishing their mission. World War II SAC aircraft were being phased out, being replaced first by the B-47 and later by the B-52. The B-47 was fitted with two barrage jammers to protect it from early warning and GCI radars, and tactics were developed that would enhance their jamming effectiveness and avoid self-interference. Six noise jammers with tunable receivers were installed in the B-52, and crews included an ECM operator. The B-52 also carried a chaff dispenser to confuse fire control radars associated with SAM's and anti-aircraft artillery (AAA). Just prior to the Vietnam War improved receivers and analysis systems, improved noise jammers, communications jammers and infrared flares were installed on B-52's. The Navy's strategic responsibilities during the cold war period also required that its planes have the capability to penetrate the Soviet air defense system, and the A-3 aircraft and later the A-5 were equipped with countermeasures systems. The Navy aircraft were not only smaller than SAC aircraft, but were more weight-sensitive due to limitations imposed by aircraft carrier operations. As a result their countermeasures systems had severe size and weight constraints, which steered the choice of equipment away from noise jammers and toward the lighter deception jammers. The power level of a reflected radar signal is quite small; deception jammers which retransmit the enemy's radar signal can be relatively low-powered and, therefore, smaller and lighter than noise jammers. Several hundred of these jammers were built and installed on A-3 and A-5 aircraft. The Cuban missile crisis of 1962 generated a requirement for a deception jammer that was effective against the Soviet missiles deployed in Cuba; it was developed in a 30-day, around-the-clock effort. Several systems were installed in Navy aircraft and readied for use, and formed the basis for the Navy's deceptive countermeasures capability which was to be greatly expanded during the Vietnam War.

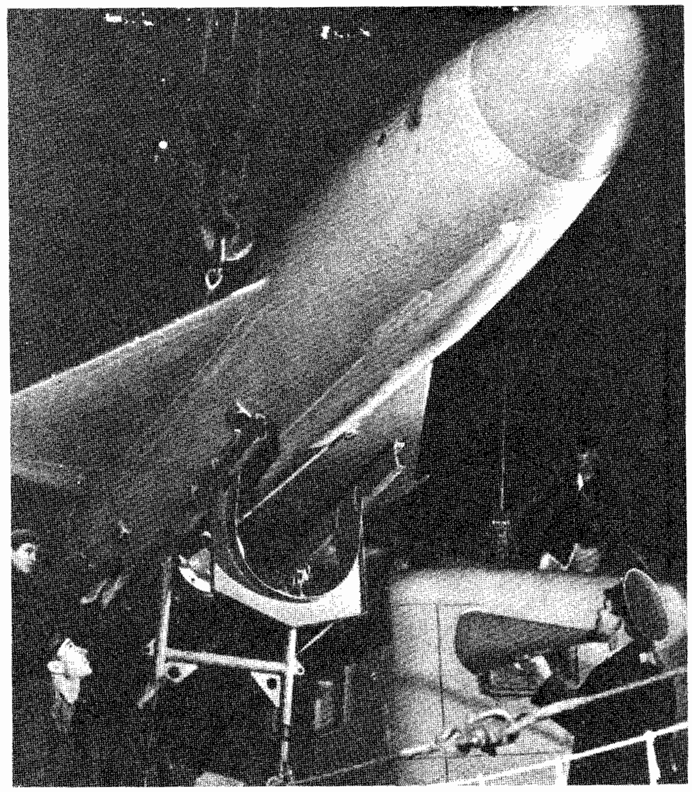


NAVY EA-3B AIRCRAFT EQUIPPED WITH NOISE JAMMERS

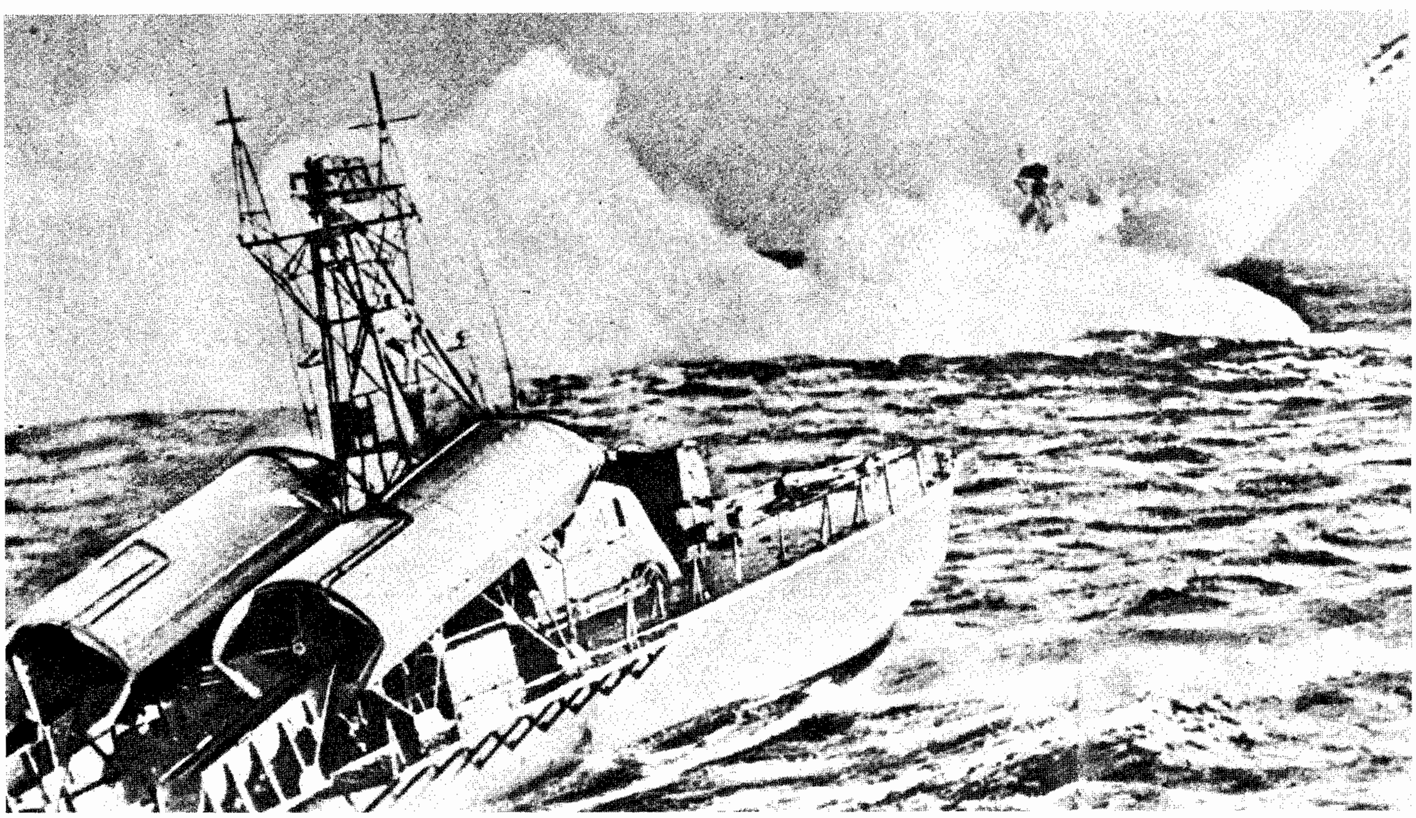

B-52 BOMBER OF THE US AIR FORCE'S STRATEGIC AIR COMMAND

Chaff and flare dispensers for internal and external installation were also developed by the Air Force and Navy as a cold war measure, to supplement onboard jammers and to provide a measure of protection against threat systems not affected by jamming. The AN/ALE-1 and AN/ALE-2 chaff dispensers were developed during this period, with the AN/ALE-1 being internally mounted. Both dispensers carried chaff in packages which were shredded mechanically before being released. Forward-launched chaff rockets were also developed during this period.

During the various conflicts in the Middle East since World War II, the lack of effective electronic warfare techniques resulted in heavy losses on both sides. The Israeli destroyer EILAT and a merchant ship were sunk near Port Said in 1967 by Soviet-made STYX missiles. In the October 1973 clash, Arab ground forces made effective use of communications deception and jamming, and their surface forces inflicted severe losses on Israeli aircraft by means of SAM's and mobile and transportable radar-directed guns until the Israelis countered these measures by changing their tactics, bringing in airborne jammers and using chaff and decoy flares for aircraft self-protection. They also learned to frustrate the STYX anti-ship missiles by firing rapid-bloom chaff while executing evasion maneuvers.



SOVIET "STYX" SURFACE-TO-SURFACE GUIDED MISSILE BEING LOADED ABOARD PATROL BOAT



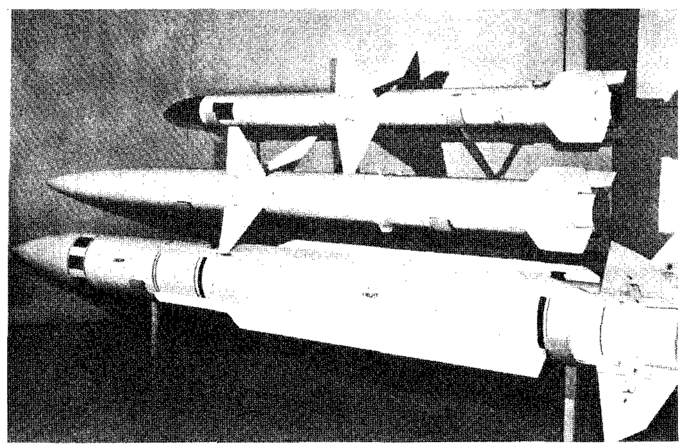
SOVIET "KOMAR" CLASS GUIDED MISSILE PATROL BOATS FIRING "STYX" MISSILE

THE VIETNAM WAR

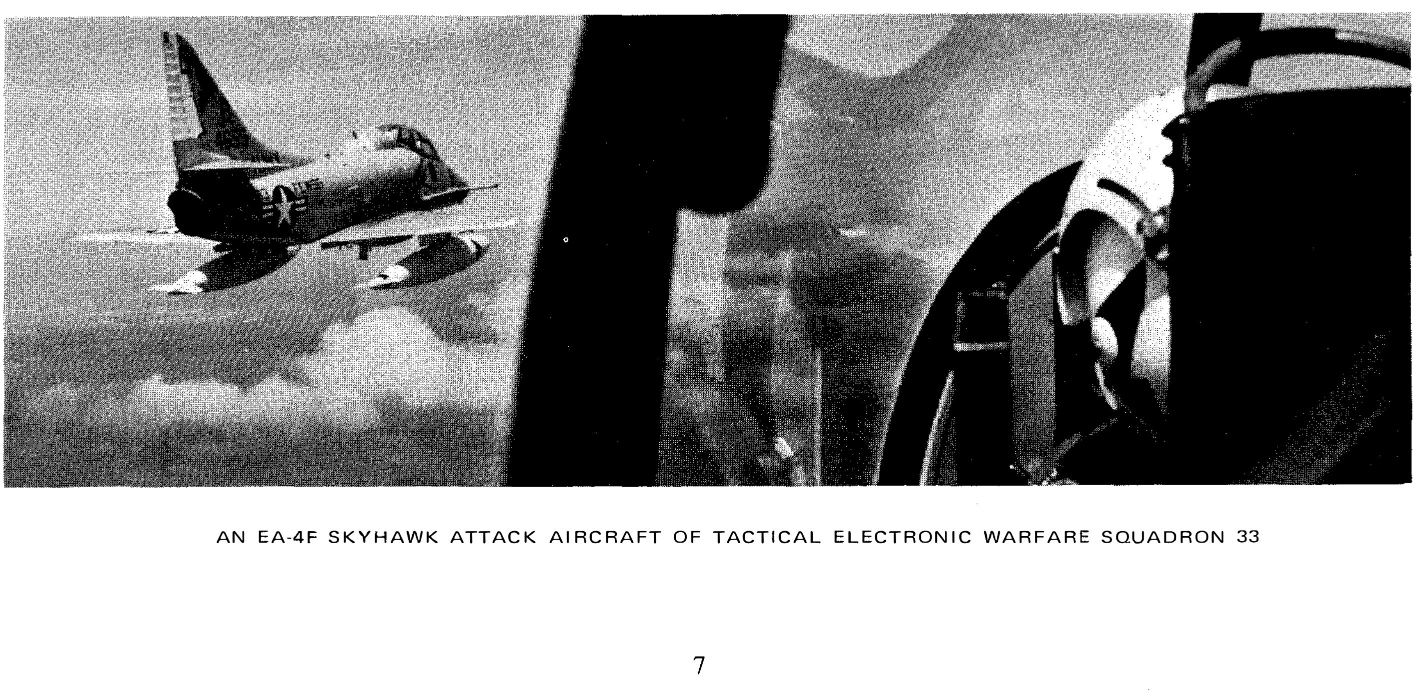
The Vietnam War resulted in the first major confrontation between tactical air power and radar-guided surface-to-air missiles and guns. The Soviet SA-2 missile, introduced early in the war, proved to be very effective; the initial loss rate of U. S. aircraft to this weapon was unacceptably high. By 1972, the use of countermeasures and evasion tactics had reduced the loss rate dramatically, with the North Vietnamese firing large numbers of missiles for each aircraft that was shot down. At the beginning of the war, Navy tactical aircraft such as the F-4, F-8 and A-4 were not equipped to cope with the surface-to-air missile threat; in an effort to provide a minimum electronic warfare capability, chaff bundles were carried under tail hooks and in the dive brakes. Heavy losses of poorly protected aircraft-to-surface weapons provided a strong motivation to develop more effective countermeasures, resulting in the initiation of a number of development programs, many of them on a quick reaction basis. Major development efforts were concentrated on radar homing and warning receivers (RHAW) and radar jammers. Air Force QRC programs led to the development of the AN/APR-25 RHAW, the AN/APR-26 missile launch warning receiver, and the QRC-160 pod-mounted radar jammer. These equipments were first deployed on the Air Force "Wild Weasel" SAM hunter-killer aircraft. Since the B-52 continued to be the principal strategic U. S. bomber, a program to augment and update its electronic warfare systems has been carried on. Many of the older jammers have been replaced by equipments with higher power, special modulations, and variable bandwidths. Installation of "set-on" receiving systems for jammer control has improved power management of the jammers.

Navy attack aircraft, operating from aircraft carriers off the Vietnamese coast, were mostly F-4's, F-8's and A-4's equipped under Project Shoehorn with deception jammers on a QRC basis. Radar and missile launch warning receivers were added later. The carriers and the aircraft they launched were protected by specially equipped EA-3B electronic warfare aircraft which monitored threat related electromagnetic radiation and provided warning and advisory messages.

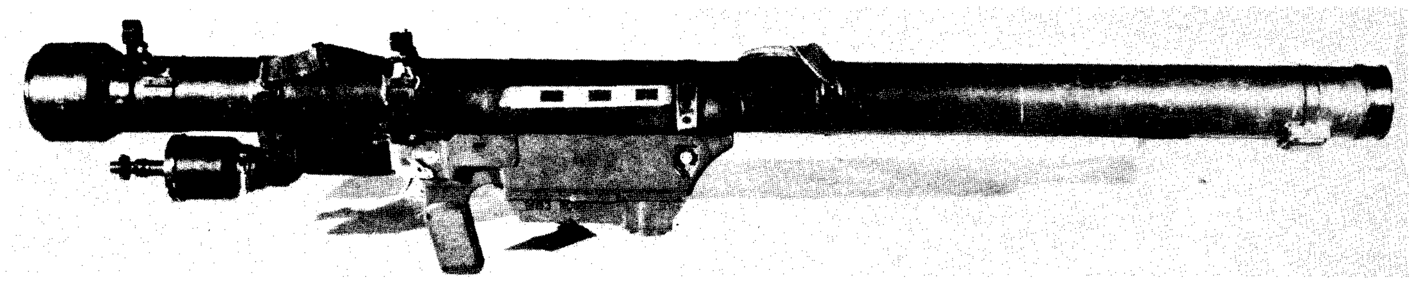
The Vietnam War also saw the first employment of air-to-surface anti-radiation missiles (ARM). ARM's could home passively on enemy radars and constituted a serious threat to any operating radar. Both SHRIKE and Standard ARM were used in Vietnam. SHRIKE, developed about 1960, is a relatively short-range missile with a 95-pound warhead. Standard ARM is larger, with a longer range and a warhead double the size of SHRIKE's. After a few radars had been destroyed, North Vietnamese radar operators developed a fear of these missiles and resorted to the obvious countermeasure–turning off the radar. Since this degraded the threat response, coordinating an ARM attack with the strike groups' arrival over the target proved to be an effective use of this weapon, even when no radars were actually destroyed. Both the Navy and the Air Force also used specially equipped aircraft for stand-off jamming of surface radars to support tactical attack operations. The primary objective of stand-off jamming was to mask the strike



U.S. ANTI-RADIATION MISSILES



AN EA-4F SKYHAWK ATTACK AIRCRAFT OF TACTICAL ELECTRONIC WARFARE SQUADRON 33



LAUNCHER FOR SOVIET SA-7 HEAT-SEEKING MISSILE

aircrafts' indications on enemy radar scopes, degrading radar acquisition and tracking capabilities, or denying detection completely. The U. S. Air Force B-66 aircraft was used extensively as a stand-off jammer. The Navy stand-off jammer, the EKA-3, began service as a bomber (A-3), was converted to a tanker (KA-3), with the stand-off jamming capability being added later. The EKA-3 carried noise jammers, set-on receivers, and a large capacity chaff dispenser, with the jammers being managed by a crew of three operators.

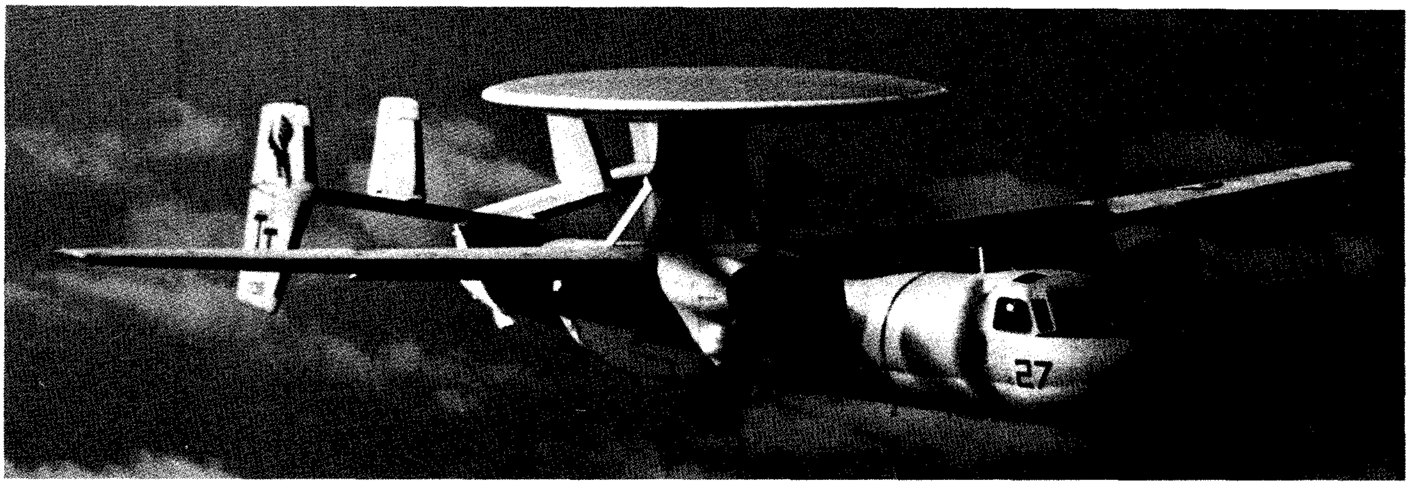
The most modern Navy stand-off jammer, the EA-6B, was developed during the Vietnam War and was deployed during its latter stages. Its primary equipment is a pod-mounted multiband jammer (AN/ALQ-99) which operates in nine bands. The EA-6B is also equipped with a systems integration receiver which allows coordination of the jamming with onboard self-protection furnished by deception jammers. The EA-6B carries three operators. The Marine Corps EA-6A stand-off jammer relies more on manual tracking than the EA-6B, being equipped with the AN/ALQ-76 jammer and multipurpose AN/ALQ-31A jammer pods which can house any of eight alternate jammers. The EA-6A requires only a single jamming operator and is equipped with deception ECM for self-protection.

The Soviet SA-7 short-range tactical infrared (IR) guided missile was introduced by the enemy late in the war and achieved a high kill rate against low, slow aircraft. The initial high loss rates to the SA-7 generated an increased interest in IR countermeasures; helicopter and gunship crews were equipped with Very pistols from which they fired flares in the direction of approaching SA-7's. Other countermeasures efforts included installation of engine IR suppression devices, steps to reduce sun glint, application of low IR reflective paint, and the development of IR warning receivers and IR jammers. These developments were late in maturing and relatively few aircraft had been equipped when the war ended.

When the battleship NEW JERSEY was reactivated for coastal bombardment of Vietnam it was protected by a special, custom suite of EW equipment assembled from available equipments in record time. The equipping of NEW JERSEY with an EW defense suite was evidence of the increasing appreciation of the need for shipboard tactical EW systems, even for ships with heavy armor. The requirement to protect surface ships from radar-guided missiles resulted in development of the SHORTSTOP shipboard tactical threat reactive system being initiated in 1967. Two complete systems were built. One was deployed in the USS BIDDLE (DLG-34) and has been tested under combat conditions, while the other system is installed at Dam Neck, Virginia for training and evaluation.

AN EA-6B INTRUDER ATTACK AIRCRAFT OF TACTICAL ELECTRONIC WARFARE SQUADRON 129

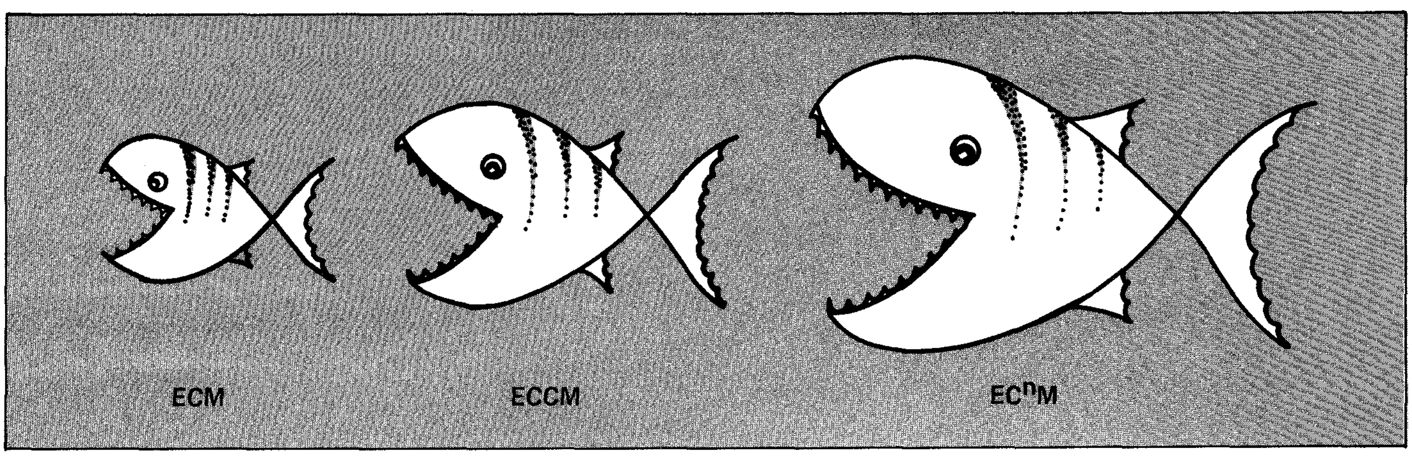
NAVY ELECTRONIC WARFARE CAPABILITIES



E-2A HAWKEYE AIRBORNE EARLY WARNING AIRCRAFT

As weapon systems become more sophisticated and rely more heavily on electronic sensors, electronic signal processors, computers and automatic trackers, they become more vulnerable to the techniques and equipments associated with electronic warfare. Electronic warfare equipments and techniques are usually developed as reactions or countermeasures to new enemy weapon systems or capabilities. As each countermeasure becomes operational, it induces an enemy action aimed at reducing or nullifying its effectiveness. This escalation of capabilities is eventually halted by the necessity of facing up to various real-world trade-offs. An aircraft can be made increasingly invulnerable to enemy weapon systems by installing additional EW systems, for example, but these systems impose weight, space, maintenance and cost penalties on the aircraft design, at the expense of the number of weapons that can be carried or fuel capacity. In a similar fashion, if extremely sophisticated features which would make a radar virtually jam-proof were to be designed into it, the cost might well be prohibitive, and in any case would be so high that procurement of the new radar in large quantities would not be feasible.

In order to develop appropriate countermeasures, the practitioners of electronic warfare must rely heavily on inputs from the intelligence community, and may design, manufacture and install the sensors required to collect information on enemy systems. Detailed reconnaissance information may also be needed to develop electronic warfare techniques and procedures for exploiting enemy electromagnetic radiations and for deceiving the enemy's electronic sensors. It is this close relationship between intelligence, reconnaissance and electronic warfare that led to the formation of the REWSON Office of NAVELEX, whose major function is the planning and development of electronic warfare systems and equipments.



SEEKING VULNERABLE SYSTEM ELEMENTS, EXPLOITING THEM, THEN STRENGTHENING THEM LEADS TO A CONTINUING ECM-ECCM BATTLE, LIMITED MAINLY BY THE AVAILABILITY OF RESOURCES

Electronic warfare systems, equipments and techniques in the fleet today can be broadly categorized as Electronic Support Measures (ESM), Electronic Countermeasures (ECM), and Electronic Counter-Countermeasures (ECCM). ESM systems are generally passive, and are designed to intercept and exploit electromagnetic radiations, while ECM systems are generally active, being intended to confuse or deceive enemy electromagnetic sensors. ECCM systems may be either active or passive and are intended to reduce the effectiveness of enemy jamming systems.

ESM SYSTEM OBJECTIVES

- Obtain information on enemy intentions and electronic order of battle (EOB).
- Determine state of readiness of the enemy's electronic equipments.
- Locate and identify the composition of enemy units, weapons and installations.
- Gather information useful for countering or deceiving enemy electronic systems.
- Determine the effectiveness of friendly ECM and ECCM activities.

ECM SYSTEM OBJECTIVES

- Deny or degrade the enemy's employment of electronic aids, such as radar.
- Protect against electronically controlled weapon systems and electronically actuated projectile and missile fuzes.
- Disrupt enemy communications.
- Perform manipulative and imitative electronic deception to deceive the enemy and cover own operations.

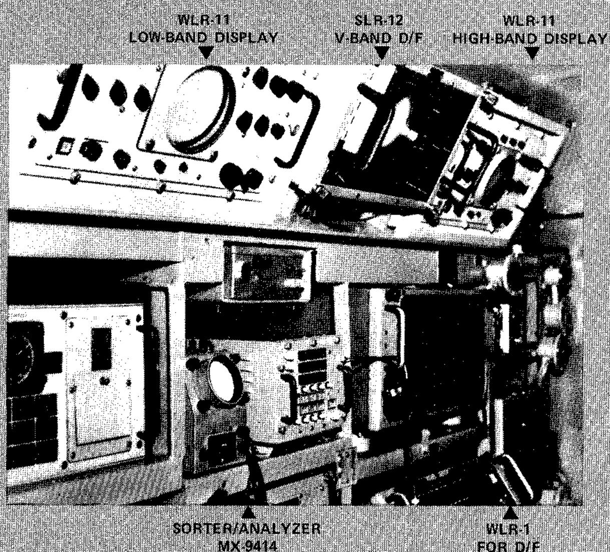
ECCM SYSTEM OBJECTIVES

- Minimize the effects of enemy ECM on own equipments.
- Deny or reduce the effectiveness of enemy exploitation of own radiations.
- Recognize and analyze for exploitation purposes the enemy's use of ECM.
- Reduce the effect of intentional or non-intentional interference.

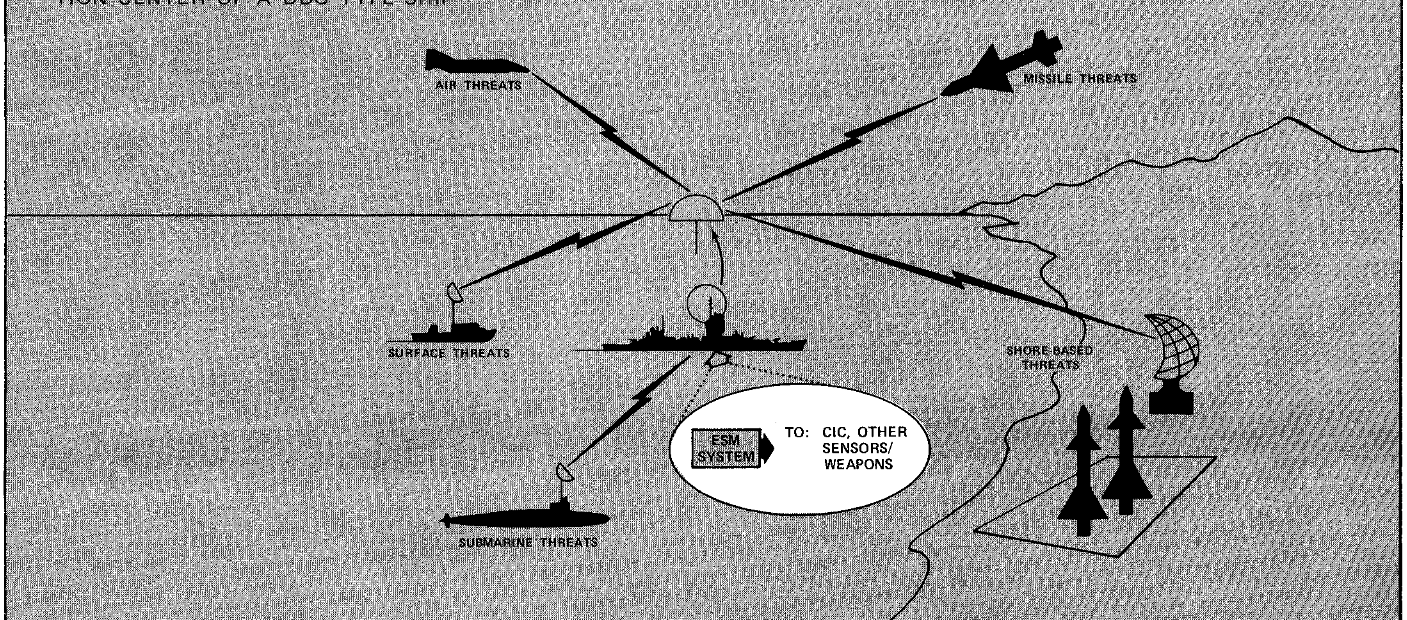
ELECTRONIC WARFARE SUPPORT MEASURES

Electronic warfare support measures (ESM) equipments search for, detect, intercept and identify electromagnetic signals. They are usually passive systems which perform functions associated with tactical reconnaissance, surveillance and warning. They may be able to obtain a bearing on an intercepted signal, and may provide for technical analysis of signal characteristics for various purposes such as emitter identification, the collection of information required to develop electronic countermeasures or counter-countermeasures, or the determination of enemy presence, location, size of force, or intentions. ESM systems range in complexity from simple, special-purpose radio receivers to very complex, multifunction computer-controlled automatic intercept systems. Even the simplest ESM system will include the following subsystems:

- Antenna(s)—One or more antennas must be provided to intercept the radiated signal. The antenna system must also provide the direction-finding capabilities if these are to be implemented.
- Receiver(s)—The combination of receivers and antennas determine the frequency range and the type of signals which can be intercepted. Receivers convert the radiated RF signal to an audio or visual signal which can be heard or seen by an operator, or processed by an associated signal processor.
- Signal Processor—In the simplest system this may be a human operator. In an automatic system it is likely to be a subsystem which measures the intercepted signal parameters, digitizes and analyzes them to determine what information they reveal, and passes the information on to a control and display subsystem.
- Control and Display—This subsystem receives the processed intercept information, reviews and/or analyzes it for purposes of control or signal identification, and prepares it for storage, display or transfer. In automatic systems these functions are usually performed by a computer.



COMPLETE ESM SYSTEM IN THE COMBAT INFORMATION CENTER OF A DDG TYPE SHIP



ESM SYSTEM DIAGRAM

ESM ANTENNAS

ESM antennas may be directional, providing greater system sensitivity and signal bearing information, or omni-directional. The physical size of the antennas depends upon their frequency range and their required directional characteristics. Low-frequency antennas are almost always larger than high-frequency antennas, and directional antennas tend to be larger than omni-directional antennas covering the same frequency range. An ESM system with wide frequency coverage usually requires a number of antennas, as coverage of more than a few octaves of frequency is difficult with a single antenna. Systems with direction-finding (DF) capabilities usually have more antennas than those which do not provide directional information. The accuracy with which an ESM system can obtain directional information is usually a function of antenna size, numbers and patterns. It is possible to obtain directional information with a single spinning antenna, but most systems are designed with multiple fixed antennas because of their greater mechanical simplicity and reliability. DF antennas intended for operation below 50 MHz usually have low directional accuracy and present severe problems for shipboard and aircraft installation. Standard antennas for aircraft and shipboard use are still employed by some ESM systems, but most newer systems require special antennas.

ESM RECEIVERS

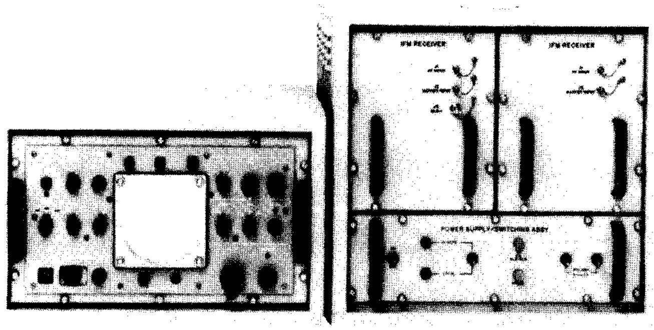
The characteristics of an ESM receiver will depend upon the application for which it is intended; the design may stress:

- Radio frequency coverage
- Sensitivity
- Selectivity
- Demodulation capabilities
- Bandwidth

The sensitivity of a receiver depends upon its bandwidth and level of internal self-generated noise. In most applications the overall sensitivity, or the minimum signal which can be detected by a given receiver-antenna combination, is of great interest. A sensitive receiver can permit reception of signals from an emitter when the emitter antenna is pointed away from the receiver. Selectivity, or the capability to tune to a single signal in an environment which contains many signals occurring simultaneously, may be very important. The receiver must be capable of demodulating the received signal or recovering the base band information. A single receiver can be equipped with demodulators to handle double sideband amplitude modulated signals, the most common radar type, or frequency modulated (FM) signals, which are less common. The receiver bandwidth capabilities should, in general, match the signal bandwidth. Most radar signals have a bandwidth of about 10 MHz, so most ESM systems have a bandwidth of this order of magnitude.

The principal ESM receiver types in use in the fleet today exhibit a wide range of fundamental characteristics. Among the more common types are:

- Broadband Crystal Video Receivers–Very simple receivers used primarily for threat warning for both ships and aircraft. They have low sensitivity, but provide satisfactory intercepts when illuminated by the main beam of a radar. When connected to an omni-directional antenna, they have a high probability of detecting a high-level signal in the band, but since they do not provide good frequency resolution, threat identification may be difficult.
- Scanning Superheterodyne Receivers–Swept or scanned through a given frequency range, these are the most sensitive and selective of the receiver types. They have the advantage of providing accurate frequency information, but have a low probability of detecting short duration signals. This type of receiver is often used for reconnaissance or surveillance, as it is capable of detecting a signal from an antenna pointed away from the receiver because of its high sensitivity.
- Instantaneous Frequency Measurement (IFM) Receivers–Perform single pulse measurement of frequency by measuring the phase difference between a pulse received over a direct path and the same pulse routed through a delay line. An IFM receiver can provide wide band coverage with good frequency resolution and is suitable for a signal search operation.
- Channelized Receivers–Provide moderate frequency resolution and increased sensitivity and selectivity by dividing the frequency spectrum to be covered into separate channels through use of contiguous RF filters. They are frequently used in threat warning receivers. These channel receivers may be either crystal, video or superheterodyne type.



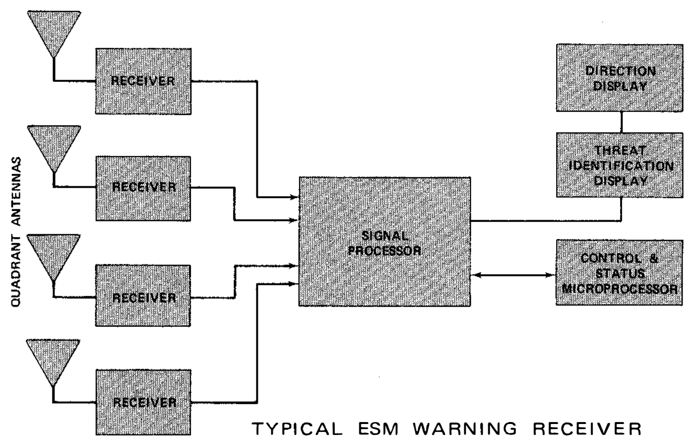
AN/WLR-11 INSTANTANEOUS MEASUREMENT RECEIVER

SIGNAL PROCESSORS

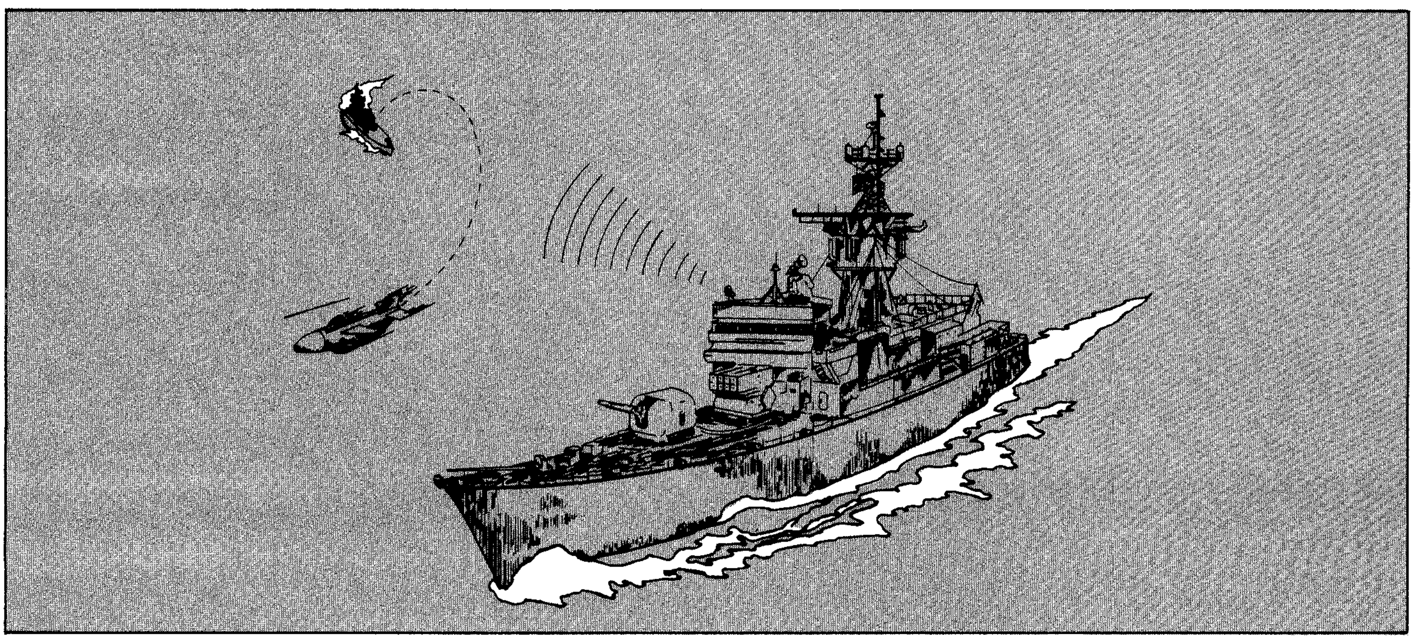
Signal processors are required in an automatic ESM system to measure the parameters of the signals intercepted for purposes of signal classification and identification. The signal parameters usually measured are frequency, pulse repetition, and pulse width. If the signal cannot be classified by means of these parameters, the scan characteristics may be measured. This is usually done only on selected signals because scan measurements take longer to make and are sometimes difficult to automate. In a system controlled by a computer or microprocessor, the signal parameter measurements are digitized and put into a format acceptable to the computer. The computer usually performs the functions of signal classification and identification, and facilitates tracking of selected signals. The signal processor may or may not be involved in determination of the direction of signal origin. This function may be performed by a separate receiver processor and the results digitized and added to the signal parameter block for transfer to the computer. A manual ESM receiver may be equipped with signal processors such as multigun cathode ray tubes, spectrum analyzers, and counters to assist an operator in manual determination of signal parameters. The human operator is very much slower than the automated signal processor but can perform detailed analysis beyond the capabilities of an automatic system.

ESM CONTROLS AND DISPLAYS

In a manually operated ESM system the operator tunes the receivers and adjusts the signal processors to permit analysis of the signal. The operator may be alerted to the presence of specific threat signals by a flashing light or audible signal. He may be furnished with a panoramic cathode ray tube (CRT) display which indicates the presence of signals by displaying a vertical line proportional to the amplitude of the signal positioned on a horizontal baseline according to the radio frequency of the signal. Establishment of signal bearing may also be accomplished by means of a CRT display. Signal searching receivers may scan across a band and stop at signals preselected by an operator on the basis of amplitude or frequency. Completely automatic systems controlled by a microprocessor or computer will accept digital data blocks derived from individual signals by the signal processor, and attempt to classify and identify them by comparison with preprogrammed data stores. These systems can classify signals as of interest or of no interest, and can identify a high percentage of the threat signals for which they are programmed. Data on signals of no interest may be discarded, while data on signals of interest may be accumulated to permit continued surveillance or development of tracks. Threat signals are usually assigned a priority rating and may be the stimulus for an operator alert.



TYPICAL ESM WARNING RECEIVER



THE MODULATION RECOVERY UNIT MEASURES VERY LOW SIGNAL MODULATION LEVELS IN ORDER TO PROVIDE THE INFORMATION NEEDED FOR ANGULAR DECEPTION BY THE ECM SYSTEM

ELECTRONIC COUNTERMEASURES

Electronic countermeasures techniques and systems are designed to degrade or deny enemy employment of electromagnetic radiation in:

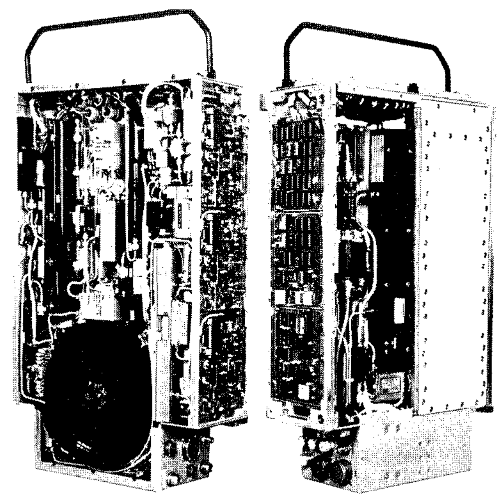
- Communications and tactical data transfer
- Radar, infrared and electro-optical surveillance and tracking
- Fire control and weapon guidance radars
- Air-to-air, air-to-surface and surface-to-air missile guidance
- Surface-to-surface and anti-shipping missile guidance

These are among the oldest forms of ECM devices, and generate a noisy signal which obscures or obliterates the desired signal in an enemy radio or radar receiver. These jammers may be used for:

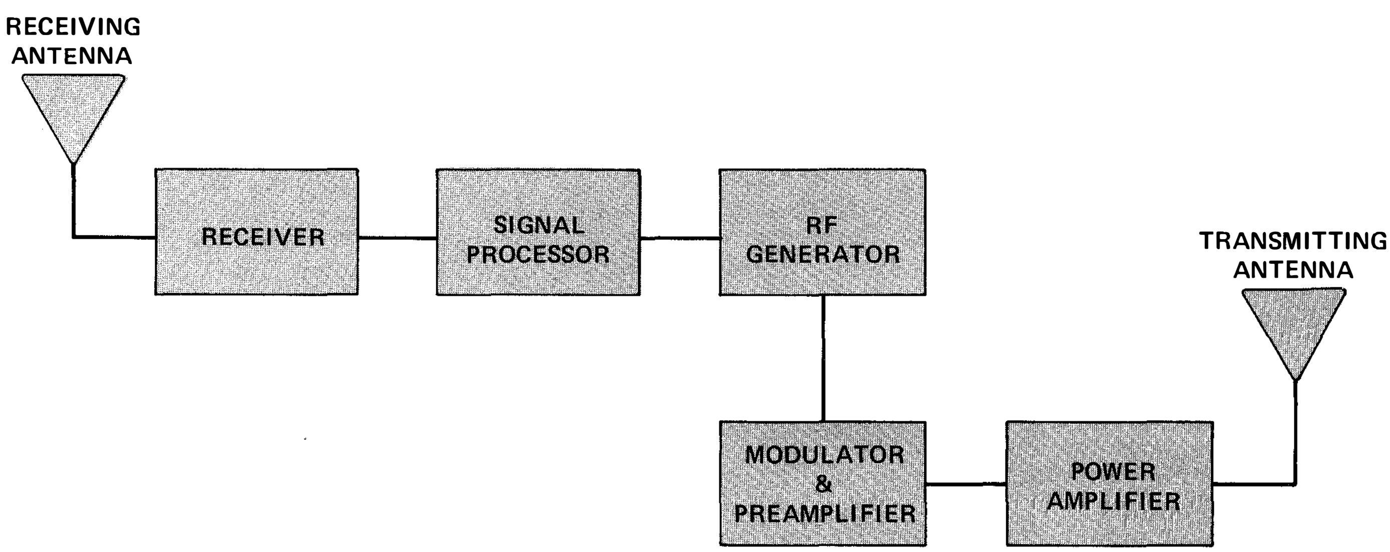
- Communications jamming–To drown out enemy radio tactical command links, both voice and digital. The jammer may operate on a single frequency selected by an operator, or sweep back and forth over a portion of the frequency spectrum (barrage jamming).
- Self-screening–To obliterate the radar return from a ship or aircraft, thereby denying range and/or angle information to the enemy radar operator.
- Stand-off jamming–To screen other friendly units, such as a strike force, from enemy early warning radar.

DECEPTION JAMMERS

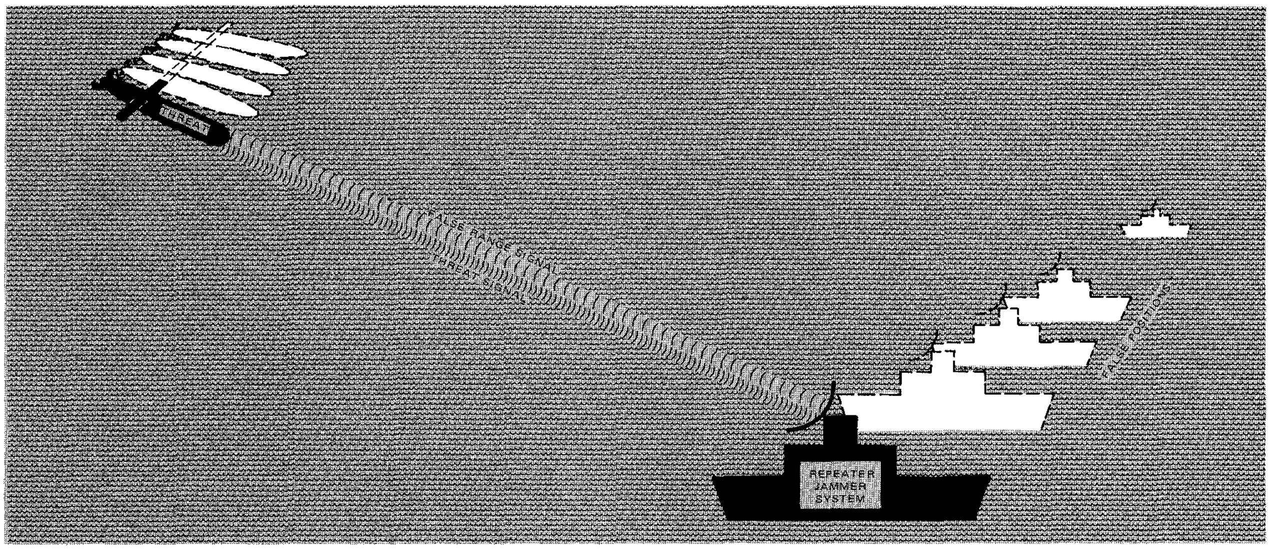
Deception jammers are usually automatic in operation and consist of a transmitter and associated receiver. The receiver monitors the signal environment and upon receiving a pulse from a threat radar, modifies it in such a way as to deceive the enemy radar and transfers it to the transmitter which radiates it back to the victim radar. The radiated pulse usually has a higher amplitude than the pulse reflected from the target, and if returned with only slight delay, may be received as a legitimate target return. Depending upon the deception technique used, the enemy radar may be presented with false target range, angle or velocity information. Deception jammers are usually used for onboard protection of an aircraft or ship, and may be effective against radar-guided missiles as well as the parent radar.



AN/ALQ-126 AIRBORNE JAMMER



TYPICAL DECEPTION JAMMER



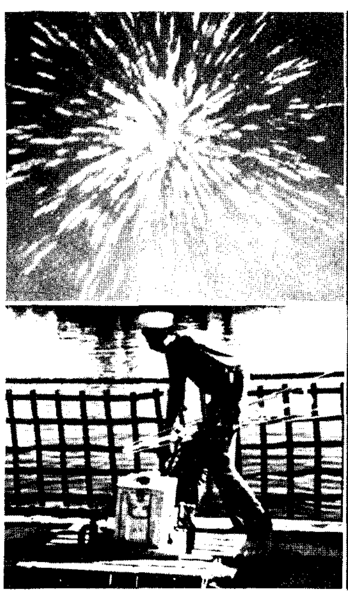
OPERATION OF A RANGE DECEPTION REPEATER JAMMER. THE TARGET RETRANSMITS THE THREAT RADAR'S RF SIGNAL, PROGRESSIVELY DELAYING THE TRANSMISSION OF THE FALSE SIGNAL UNTIL THE THREAT RADAR IS PULLED OFF TARGET.

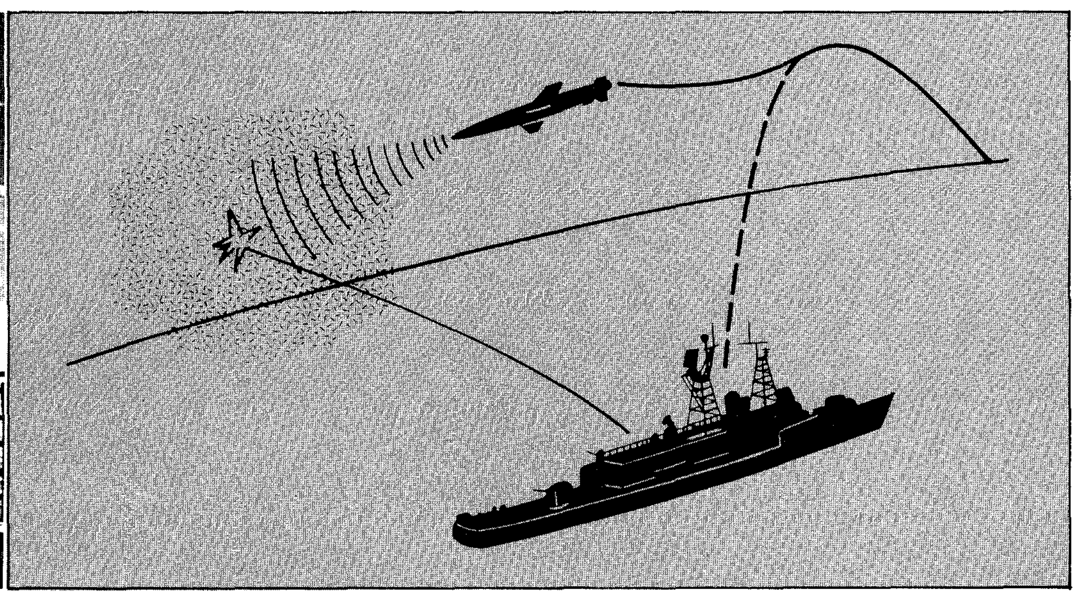
DECOYS

The decoys currently in use by the Navy consist of chaff or flares. Chaff is used to present false targets to enemy radars or radar-guided missiles. It may be dispensed in packages or bundles from an aircraft, with the bundle expanding into a chaff cloud as it hits the airstream. Ships use chaff rockets which burst and distribute the chaff cloud some distance from the ship. The chaff is cut to lengths which depend upon the frequency range of the radar to be decoyed, and are intended to confuse a radar operator by providing him with a false target, or to defeat a radar-guided missile by diverting it away from its legitimate target. Flares may be dispensed from an aircraft in the same manner as chaff, and provide high-intensity, bright targets for heat-seeking missiles such as the SA-7.

ELECTRO-OPTICAL COUNTERMEASURES

The increasing deployment of weapon systems using infrared and TV trackers, and of missiles using infrared and electro-optical seekers, has generated a requirement for effective electro-optical (EO) countermeasures. Navy EO developments have been chiefly concerned with protection of aircraft from infrared-guided air-to-air and surface-to-air missiles, and protection of ships from infrared-guided anti-shipping missiles. A considerable effort has been devoted to reducing the amount of infrared radiation from aircraft and ships, thus reducing their vulnerability to attack by this type of weapon, and particular effort has been made to devise ways of protecting helicopters and low, slow flying aircraft from surface-to-air infrared homing missiles such as the SA-7. These efforts have resulted in developments of IR warning receivers and IR jammers similar in function to the older family of radar warning receivers and radar jammers.

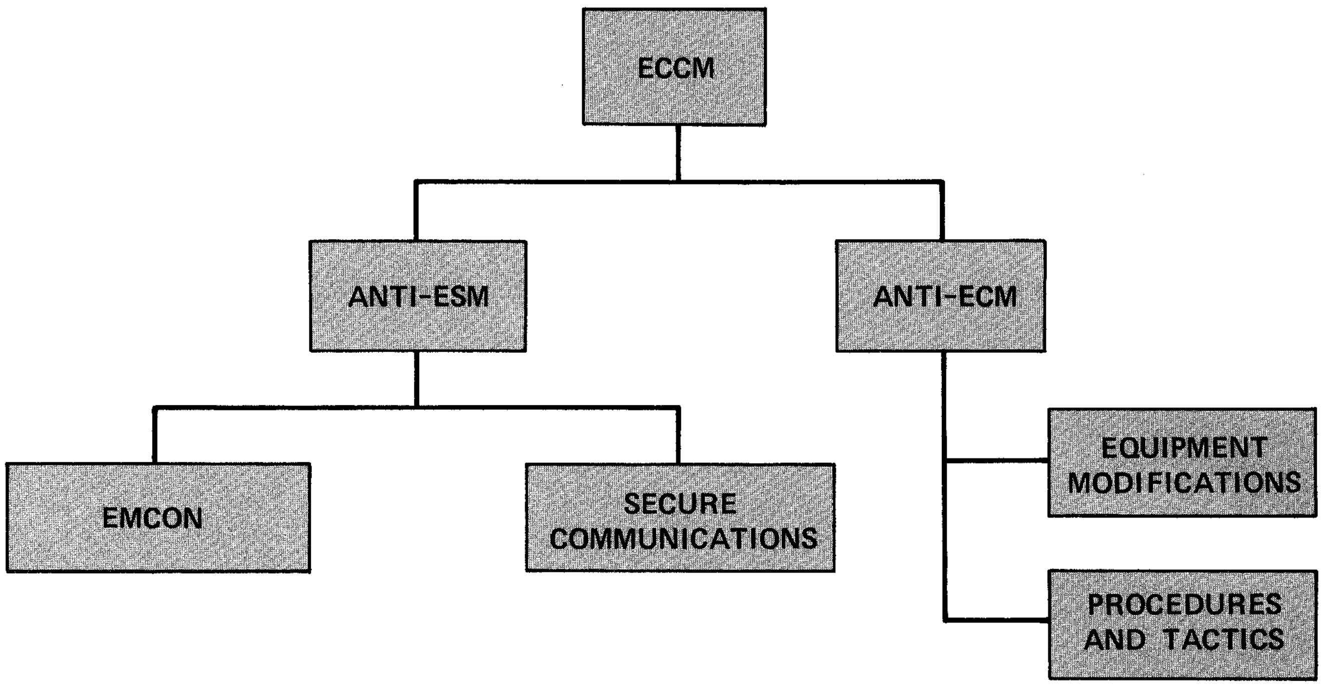




DIVERSION OF ATTACK BY USE OF RAPID-BLOOM OVERHEAD CHAFF DECOY

ELECTRONIC COUNTER-COUNTERMEASURES

Electronic counter-countermeasures are generally undertaken in reaction to enemy use of ECM, and are intended to ensure the use of the electromagnetic spectrum by friendly forces in spite of the enemy's attempts to interfere. Most ECCM techniques can be classified as either anti-enemy ESM or anti-enemy ECM.



TYPES OF ECCM TECHNIQUES

ANTI-ESM MEASURES

Emission Control (EMCON) techniques are concerned with suppression and/or control of our own radiation which may be exploited by enemy ESM systems.

EMCON does present an effective means of preventing an enemy from exploiting our more easily intercepted radiations. Secure communications are techniques and equipments used to make enemy detection and exploitation of our electromagnetic signals more difficult. Detectability may be decreased by using low-power noiselike signals or by transmitting very short (burst) signals. Communication security may also be enhanced by coding or encrypting radio communications. Simple scramblers similar to those used in overseas telephone transmissions were used in early efforts at communication security. These rather primitive methods have been replaced by more secure links using pseudo-random codes, which are usually implemented with digital transmission links.

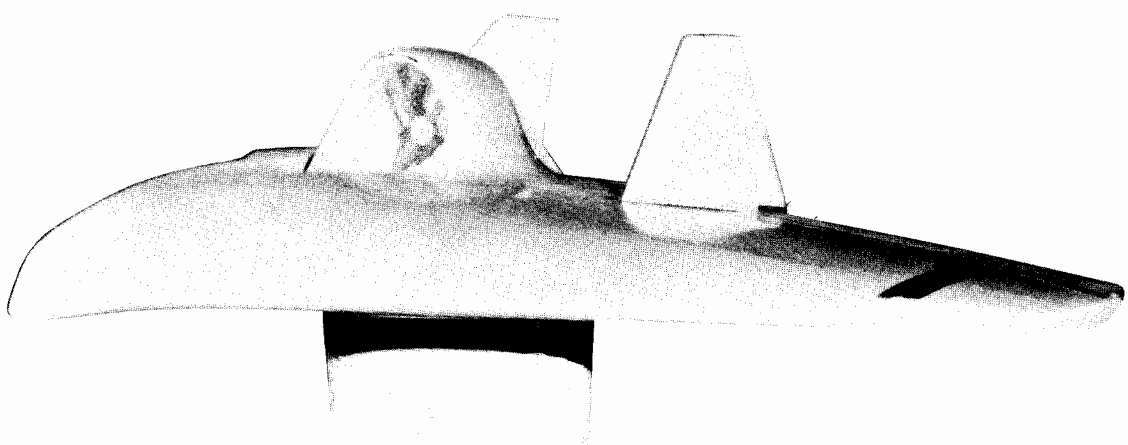
ANTI-ECM MEASURES

Anti-jam or anti-deception circuitry can be built into equipments either in anticipation of or in reaction to enemy use of ECM. Anti-ECM measures also include the use of procedures and techniques which can reduce or counteract the effectiveness of enemy ECM. The set-on of enemy noise jammers can be defeated by radars with frequency agility, or the capability to change frequency very rapidly, perhaps with every pulse. A common anti-ECM feature found on many radars is the "Dicke Fix" which consists of a limiting circuit followed by a narrow band amplifier. This arrangement limits the effect of a high-power jammer while discriminating against the jammer signal by means of the narrow band filter. Weapon systems equipped with alternate methods of target tracking can be highly resistant to ECM. If one radar is jammed, target information is derived from another radar. Or if all radars are jammed, the target tracking may be taken over by visual, TV or infrared trackers. Weapon and search radar operators can be trained to cope with ECM by adjusting receiver and display controls.

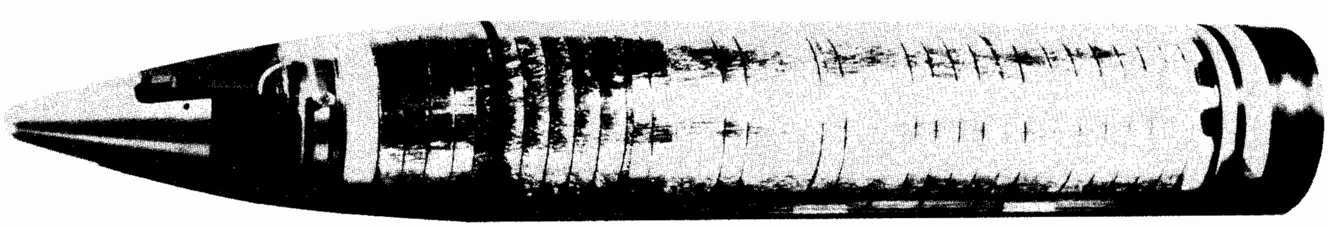
NAVY ELECTRONIC WARFARE DEVELOPMENT PROGRAMS

Programs are being carried out in the Naval Electronic Systems Command, as well as the Naval Air and Sea Systems Commands, to develop improved capabilities to meet the Navy's needs in the areas of ESM, ECM and ECCM. Some of the NAVELEX programs are:

- Zuni Chaff Rocket
- Anti-Shipping Missile Electronic Warfare Suite
- Shipboard Infrared Countermeasures
- New Signal Intercept Processing
- Passive Electronic Warfare Shipboard Systems
- Lasers
- Signal Intercept Support
- Surface Electro-Optical Systems
- Communication Security R&D
- Infrared Search and Track
- Jamming and Deception
- Ship Advanced EW
- Ship EW QRC
- Multi-Mode ECM
- Low Cost EW Suite
- Shipboard Electro-Optic Surveillance
- Ships Signal Exploitation System
- New Signals—Threat Classification and Sorting



LIGHTWEIGHT RECOVERABLE REMOTELY PILOTED VEHICLES (RPV's) CAN PERFORM THE ECM DECOY FUNCTION



U.S. NAVY CHAFF ROCKET

In cooperation with NAVAIR and NAVSEA, NAVELEX is developing EW equipments for specific ships and aircraft. Security restrictions prevent a complete listing of all of these programs, but a few typical Navy EW programs suitable for a non-classified discussion will be described.

LOW COST EW SUITE

The Navy's unique development effort in the electronic warfare area is the program which has become known as the Low Cost EW Suite. Its conceptual goal calls for the development of a modular family of EW systems which were specified in terms of ceiling costs rather than performance specifications. Contractors were furnished with system goals, a definition of the threat, a list of candidate platforms and operational scenarios, and were asked to develop a family of electronic warfare suites for various applications at fully installed fixed prices ranging from $300,000 to $1.4 million. Systems developed under this program are intended to equip:

- 60 ships with threat warning capability, wide area electronic surveillance and deception ECM at a unit installed cost of $1.4 million.
- 115 ships with threat warning and wide area surveillance at a unit installed cost of $500,000.
- 125 ships with threat warning capability only at a unit installed cost of $300,000.

The initial operational capability date is the summer of 1977. The program will result in all major combatant forces having an EW capability appropriate to the threat and the nature of their mission, if funding and equipment production qualities are maintained at the levels currently authorized.

TACTICAL ELECTRONIC WARFARE DECEPTION SYSTEMS (TEWDS)

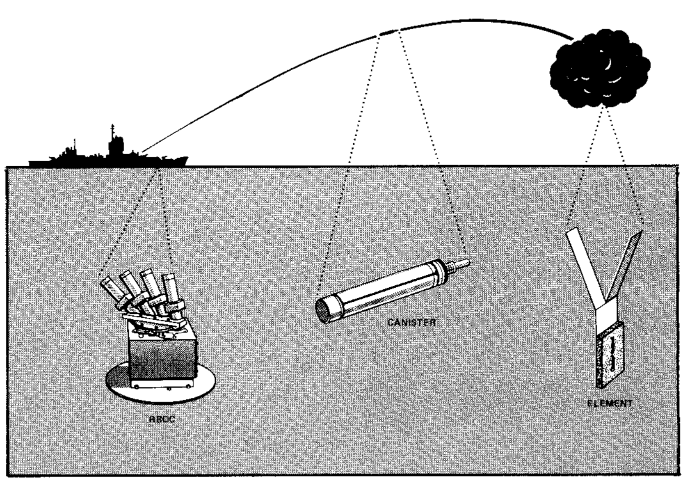
This program is to develop equipments and techniques which can be employed against anti-ship capable missiles (ASCM), and is to produce a family of decoy devices to be used in a variety of operational engagements and shipboard EW system configurations, and against missile seekers of various types. TEWDS is related to, and draws requirements from, the Ships Advanced Electronic Warfare and Shipboard Infrared Countermeasures programs.

EVALUATION OF NAVY ELECTRONIC WARFARE SYSTEMS (ENEWS)

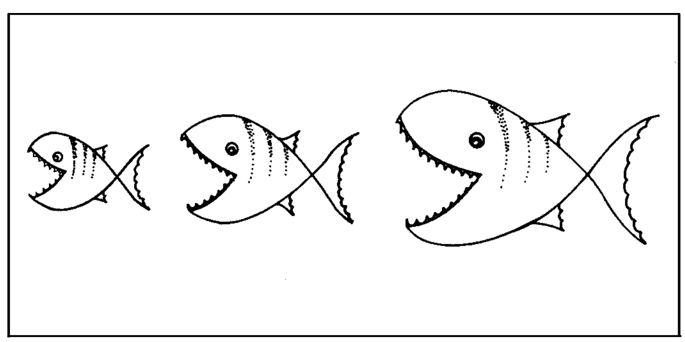
ENEWS simulates various enemy missile threats with hardware devices and computer models. The resulting simulations can be analyzed and exploited in order to reveal the vulnerability of the threats to countermeasures, which should lead to increased fleet operational readiness through improved countermeasures capability. Simulations of certain missiles have been fabricated and are currently in use. The original project has been expanded to include a coordinated simulation program, which can meet Navy requirements in terms of quick response to newly discovered threats, and assist in the determination of optimum countermeasures. Threat scenarios which have been developed for an open-ocean attack on a U. S. task force have been used in the evaluation of ESM and other EW systems.

SHIPBOARD INFRARED COUNTERMEASURES (IRCM)

The IRCM program is to develop techniques and equipments to suppress IR radiation from ships and to develop decoying and degrading active IR countermeasures. Infrared signature suppression techniques are used to make a ship a less conspicuous target. The capability of IR seekers to acquire a ship can be decreased by eliminating the differences in radiation between the ship and the sky and sea background. Thermal radiation from a ship can be reduced by shielding the stacks, using paints having low IR emissivity, and cooling hot surfaces with air or water, while IR seekers can be decoyed by flares launched as the seeker approaches the ship.



INFRARED AREA DECOY (IRAD) SYSTEM COMPONENTS



ELECTRONIC WARFARE THREAT ENVIRONMENT SIMULATION (ECHO RANGE)

This is a surface facility which provides instrumented live simulations of threat weapons and related ancillary equipments. It is used to develop EW tactics and to evaluate the effectiveness of EW techniques and equipments. Simulated equipments are realistically arranged, and facilities include operations control vans, communications and support equipment. The range is equipped with radar and visual tracking equipment which maintains a continuous record of the positions of aircraft involved in the tests.

INTEGRATED EW SYSTEM

This development is intended to provide a versatile integrated EW defense system for tactical aircraft. The common system will perform the functions of radar homing and warning, missile warning, self-defense ECM, and threat recognition, which are presently performed by discrete systems. It will incorporate automatic control of active ECM systems and automatic dispensing of chaff, flares and decoys as required by the tactical situation, and will also provide data for anti-radiation missile targeting. The project is still in an early stage of development, and the model of aircraft in which it will be first introduced has not yet been determined.

TACTICAL AIRBORNE SIGNAL EXPLOITATION SYSTEM (TASES)

TASES is a design for a new carrier-based electronic warfare aircraft ESM system to provide support to a task force commander. The airframe will be a derivative of the S-3A ASW aircraft; it will be equipped with a complete suite of ESM receivers, and will be capable of performing reconnaissance using radar and other sensors. The TASES system will use many of the automated features built into the S-3A aircraft, including a highly capable central digital computer and computer-activated displays. The small size of the aircraft, with a crew of four, will be compensated for by the high degree of automaticity incorporated in the system.

AIRBORNE INFRARED COUNTERMEASURES

The Airborne Infrared Countermeasures project is to develop equipment for protecting Navy and Marine aircraft from air-to-air and surface-to-air IR-guided missiles. The devices and equipments under development include IR warning receivers, missile launch detectors, active IR jammers and flares.

ELECTRONIC WARFARE SYSTEMS OF THE FUTURE

The electronic warfare systems of the future will be shaped by advances in electronic technology and changes in weapon system designs. The two factors are not independent, since electronics technology influences weapon system design as well as electronic warfare equipments. Some of the trends in technology that are apparent are:

- Increasingly dense electronic signal environments associated with all military operations and with industrial areas.

  Use of higher radio frequencies for both communication and non-communication services.
- An increased use of digital modulations and digital signal processors both for radio frequency transmissions and for signal and information processing.
- An increased use of solid-state components, particularly at the lower power levels.

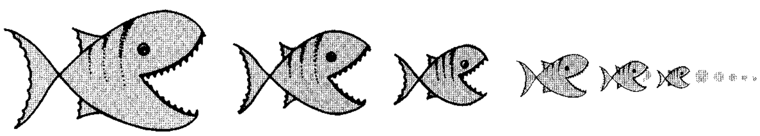
  An increased use of integrated circuits rather than discrete components.

  An increased use of miniature computers and microprocessors for automatic signal processing and system control.

Some recent trends in weapon system designs were well documented in the 1973 Middle East War, in which the Arabs employed the Soviet-built SA-6 surface-to-air missile and the ZSU-23 mobile anti-aircraft unit with its radar-directed 23mm quad battery. The SA-6, in particular, caught the Israelis by surprise because their warning receivers could not detect the CW illumination that was used as a homing signal by the SA-6 missile, and their jammers could not jam it successfully. The trends in weapon system development are:

- Development of highly mobile, fast reacting weapon systems.
- Development of guidance systems highly resistant to ECM, with fall-back alternate modes of operation.
- Increased use of electro-optical and infrared target and missile tracking devices.

The reaction of electronic warfare system designers to these trends is to develop "smart" systems. Defense suits for aircraft and ships are evolving from collections of independent receivers, jammers and chaff and decoy dispensers into integrated systems in which the sensing elements (receivers) detect and identify threats and a central control unit selects the optimum combination of defenses necessary to neutralize the threat. EW system design is becoming more and more dependent on computer processing, as a human operator is not able to handle the dense signal environments that typify modern military operations. Because of size, weight, and particularly cost limitations, there is more emphasis on smart responses and management of jammer power rather than implementing a high power level response. An effective increase in jamming efficiency can be achieved by tuning the jammer accurately to the threat radar's operating frequency, selecting the optimum modulation to confuse the threat guidance system, and pointing a steerable antenna at the victim receiver. Implementation of an adaptability to new threat types will be accomplished by replacing hard-wired threat identification logic with computer programs (software) that can be easily changed as threat characteristics change. The underlying principles of electronic warfare will not change in the future. As more sophisticated weapon systems are introduced, smart EW systems will be designed to counter them. These same smart defense systems will then be countered by weapon system advances in a never-ending cycle.

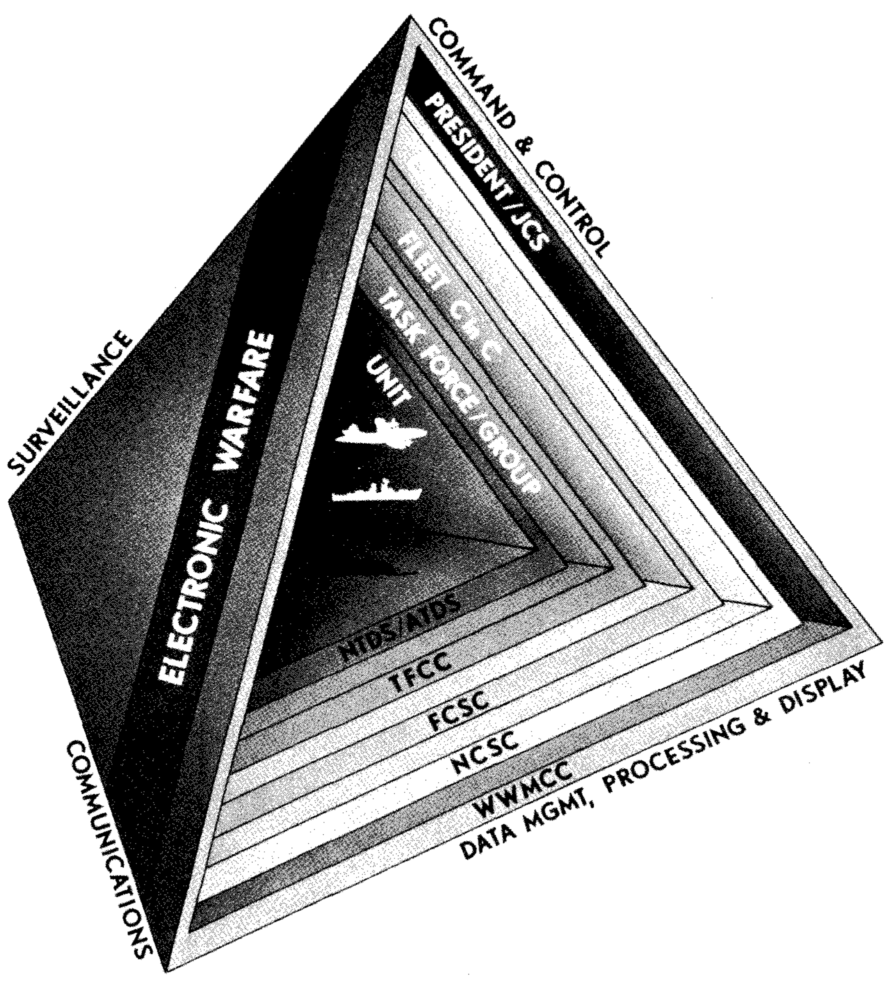


NAVELEX TETRAHEDRON

The NAVELEX tetrahedron symbolically depicts the broad matrix of electronic systems and equipments required to support the Naval operating forces, and the command relationships between the various mission arenas.

Command and Control is at the apex of the tetrahedron; electronic equipment and systems must be developed, procured, and supported for use at all levels—from the commander of the individual ship, aircraft, submarine, or Marine Corps unit to the President and Joint Chiefs of Staff—in controlling the forces under their command. The Command and Control function is supported by the development of appropriate surveillance, communications, and data management, processing, and display systems. Surveillance and Communications system developments also directly support implementation of NAVELEX's Electronic Warfare mission.

NAVELEX addresses further responsibilities as the central manager for Navy and Marine Corps electronic technology by carrying out a vigorous research and development program, and by developing, procuring and providing support for electronic systems for navigation, air traffic control and a variety of other requirements.



NAVAL ELECTRONIC SYSTEMS COMMAND