Electronic combat is a deadly game of measures and countermeasures. Superior equipment is important, but the combatants must use it with cunning and skill.

This hunter/killer team of an F-4E (foreground) and an F-4G Wild Weasel radar suppression platform from the 37th Tactical Fighter Wing at George AFB, Calif., practices its craft. The F-4 is the third generation of aircraft to be outfitted for the Wild Weasel role.

BY JOHN T. CORRELL
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With Waveforms

IN THE world of electronic combat, skill and cunning are frequently as important as superior weapons and systems. The principle is illustrated by the task assigned to Wild Weasel aircrews flying SAM suppression for Operation Linebacker II in December 1972.

The United States, seeking a conclusion to the Vietnam War, sent its heavy bombers and everything else it could lay hands on to pound Hanoi and Haiphong relentlessly for eleven days. Hanoi itself was protected by the most lethal defenses in North Vietnam, including a cordon of SA-2 surface-to-air missiles deployed on all approaches to the city.

Suppressing the radar-controlled SA-2s was the job of the Wild Weasels, organized for that very purpose in the early part of the war. There weren't many of the Wild Weasels, though, and with attacks continuing around the clock, only a few Weasels at a time could be over Hanoi to support the typical Linebacker II bomb run.

"If anybody had told me in pilot training that I'd be going to downtown Hanoi at night with only two bullets [Shrike antiradiation missiles] to cover five SAM sites for twenty minutes, I'd probably have turned in my wings right then," says Tom Floyd, a Weasel pilot who was there. "But we did it."

Sometimes they did it by straightforward assault on the SAM sites, at other times with distraction, intimidation, and maneuvering. The basic idea was to neutralize a part of the SAM defenses long enough for the bombers to get through and deliver their ordnance. Sometimes the SAMs won the engagement, and sometimes the Weasels did.

Vietnam was the war in which electronic combat came of age. It introduced the use of surface mis-

and Wits

sile defenses linked to target-tracking radars to shoot down penetrating aircraft. This war also saw large numbers of US fighters go into battle with ECM (electronic countermeasures) pods slung under their wings to help them avoid engagements. B-66 bombers were given an E prefix and adapted to jam North Vietnamese communications and radars. And in 1965, the Wild Weasels were invented to stalk and fight the SAMs with lethal electronics of their own.

Col. Sam Peacock, a former Weasel now working in the Pentagon, says that merely going into sequence for a Shrike launch was often enough to intimidate SAM batteries, making them shut off their radars. If the battery did fire, the Weasel might duck behind a hill to break the radar's lock or "take it down" in the classic Weasel maneuver—an afterburner dive with a hard turn at the bottom that the missile couldn't follow.

Skill and cunning work both ways, of course. The SAM radar emitted a telltale signal when launch was imminent. The Weasels were alert for it. Consequently, the SAM operators learned to put up phony signals to fake the Weasels. They also surprised them by firing the missile in the general direction of the aircraft, then waiting until the last moment to turn on the tracking radar to correct the trajectory.

This deadly game of measures and countermeasures, feints and deceptions mixed in with an occasional bullet between the eyes, is the standard stuff of electronic combat. The objective is seldom to win a direct duel with the enemy. More often, the electronic warriors are satisfied if they can pull the enemy off balance sufficiently to allow some main battle event, such as attack of an enemy airfield, to suc-

ceed. Each side tries to preserve the electromagnetic spectrum for its own use while degrading, disrupting, or—if the odds are right—destroying the opponent's radar, communications, and other electronic assets.

A probing pulse from a ground radar can be either a threat or an opportunity. If the seeker stays on the air long enough, an antiradiation missile can be sent riding down his beam. A jammer can flood his radar screen with static. Alternatively, the penetrator might manipulate the signal bouncing back to the defender's antenna to feed him false information.

Measures and Countermeasures

In the 1960s, the radar-SAM combination forced penetrators to low altitudes where they could screen themselves behind natural terrain and the curvature of the earth. The fighters began to carry ECM pods routinely for electronic cover, then upgraded to "smart" frequency-hopping pods that adjusted automatically to the jamming requirements of the moment. Defenders soon took the edge off low-level tactics with airborne pulse Doppler technology that could look down and pick out low flyers from the ground clutter on the radarscopes. The tactical electronic environment grew in density as well as in complexity. It is said that combatants in a European war would have to contend with a million pulses of electromagnetic energy per second.

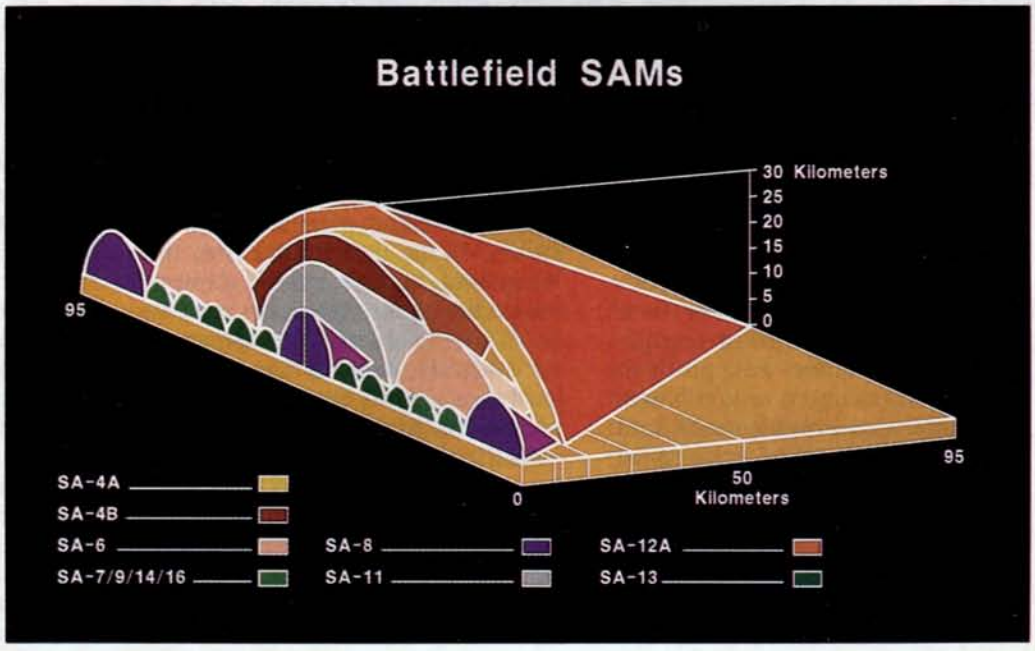
In the fifteen years since Linebacker II, the jammers and the Weasels have improved their weapons and added to their bag of tricks, but so have the Soviet-equipped shooters on the ground. This is especially true along the Warsaw Pact border with Western Europe, where the Soviets have concentrated a thick barrier of their best mobile SAMs *(see accompanying diagram)* and state-of-the-art AAA guns like the ZSU-X, which can shoot on the run.

The Soviet Integrated Air Defense System (IADS) has 7,000 radars for early warning and ground-controlled intercept, 13,000 SAM launchers, 12,000 antiaircraft artillery pieces, and 5,300 fighter-interceptor aircraft. Part of this is older equipment. Even the SA-2, upgraded several times since Linebacker II, is still in service at some 350 sites. But some of the newer SAMs are controlled by frequency-hopping monopulse radar, which reads range and direction from the same return and which welcomes a garden-variety jammer strobe as one more bit of useful information. Vietnam-era tactics will not beat this grid.

"There's nothing today that I'd call a Soviet death dot—a weapon that can follow you into the bowels of the earth—but it takes more than maneuvering to survive," says Col. Richard M. Atchison, Director of

Electronic Combat Operations in the Office of the DCS/Plans and Operations at Hq. USAF. "There is no one thing you can put on an airplane that is sufficient by itself to protect you. It takes a mix of equipment, strategy, and tactics."

It's an open question whether the modern Weasels with their F-4G aircraft and High-Speed Antiradiation Missiles (HARMs) would be able to intimidate these SAM operators.



Soviet tactical air defenses incorporate interceptors, antiaircraft guns, and this layered coverage of surface-to-air missiles. These defenses are in depth and pose a threat all the way up from low altitudes and out to a range of thirty kilometers.

Even though it is unarmed, the Grumman EF-111A Raven is one of the most potent aircraft in the Air Force's inventory because of its ability to jam enemy electronic defenses. The Air Force has forty-two EF-111s divided between the 366th TFW at Mountain Home AFB, Idaho, and the unit this Raven belongs to, the 20th TFW at RAF Upper Heyford in the United Kingdom. (Photo © Mi Seitelman/IDI)

Soviet doctrine prescribes emission control, but does not leave the operators much discretion to interpret orders. If they shut down at an unauthorized time, they face a firing squad. But that's the next day or the next week. The threat of the Weasels is immediate. After a few nearby sites are blown away, the discipline of the SAM operators would be tested severely.

To screen its own forces in battle and to degrade the opponent's command and control, the Soviet Union is prepared to conduct large-scale jamming of radars and communications. Its main airborne platforms would be the Il-20 Coot-A and the An-12 Cub-C and D—modified versions of turboprop transports—and the J and K models of the Mi-8 Hip medium helicopter. Ground-based jammers, assigned to radio-electronic combat battalions of the Army, proliferate.

The New "Mainstay" AWACS

The old Soviet airborne warning and control system, the Tu-126 Moss, is limited in effectiveness and has not been a major concern for the West. The new Mainstay AWACS, topped by a "Flat Jack" radome, seems to be another matter. "Now in production, this modified Il-76TD has a true overland look-down capability," says the latest edition of *Soviet Military Power*, published by the US Defense Department in March. "In addition to a new identification, friend or foe [IFF] system, this aircraft may have a comprehensive electronic countermeasures complement."

The Russians have been practicing this game, which they call "radio-electronic combat," since the time of the czars (they jammed a Japanese radio with a spark transmitter in 1904), and they are adept at it. Their better systems rank with the best.

Soviet technology in this field sorts into three time categories, says Brig. Gen. John A. Corder, Director of Electronic Combat for Air Staff R&D. Systems brought out in the 1960s and early 1970s were "poor to fair," but were produced in large numbers.

"Beginning in the mid-1970s, with the advent of monopulse and pulse Doppler processing, the ability [of their airborne radars] to look down and find things in the clutter was improved," General Corder says. The Soviets had not yet mated these radar returns with weapons for a look-down/shoot-down capability, but "no longer could you run around at low altitude and not be found. And with monopulse processing, the ability to hide yourself in angle [azimuth and elevation] was degraded. I'd start calling this pretty good technology, and the numbers were still there." The MiG-23 interceptor represents this category.

In the 1980s, General Corder says, "we begin to see excellent technology in terms of look-down/shoot-down from an airborne threat. The numbers are fairly low right now. They probably won't be significant until the early 1990s, and there won't be as many of them as we've seen before, I don't think, because they cost a lot of money."

Soviet Military Power also reports progress by the USSR on radio-frequency (RF) weapons. Several applications are possible, one of them being the degradation of military electronics. Soviet researchers have generated single pulses of better than a billion watts and have sustained repetitive pulses of greater than 100 million watts.

Punching Holes in IADS

Meanwhile, the US Air Force has been making some progress of its own. It still has some shortcomings, but, all in all, is probably better prepared for electronic combat than at any time in the past. Its major electronic combat aircraft have come into service in the past ten years. Most of its countermeasures equipment has been upgraded or is being upgraded now. Indications are that the United States will be able, in the years ahead, to stretch out the slim lead it now holds over the Soviet Union in this area. Electronic combat has also become a regular part of USAF training and exercises, which contributes both to aircrew preparation and to the mindset it takes to win in the game of measures and countermeasures.

The improvements that meet the eye most readily are those in the area of offensive electronic combat, systems and tactics that prevent the enemy's use of his radars and radios. Individual airplanes in the tactical fleet would go into battle with some countermeasures on board: jammers good enough to set up a local electronic fog, chaff to foil radars, and flares to counter threats from the infrared portion of the electromagnetic spectrum. The

F-15 has its countermeasures equipment tucked neatly inside as part of its Tactical Electronic Warfare System (TEWS), but most aircraft carry their ECM equipment in external pods. These pods, like the radars they work against, are agile frequency hoppers.

Jamming is a matter of how much electronic energy the source can blast into the contested frequency. The jammer can focus his power for intensity or diffuse it for broad coverage, but either way, it takes considerable power to dominate the enemy's large emitters on the ground and control the spectrum over a lot of territory. It isn't practical for fighters to carry jamming sets big enough to do all this. That's a job for escort aircraft that specialize in jamming.

The EF-111A Raven, operational since 1981, can reach out for long distances and disrupt early warning and GCI radars. It is effective against the densest electronic defenses known. Raven can act as a standoff jammer, or it can escort the penetrating force into the battle area. It took part in last year's US action against Libya. The EC-130H Compass Call, introduced in 1983, is a communications jammer that would work from standoff range against the enemy's command and control net. These two jamming platforms perform extremely well, but there aren't many of them. Only forty-two of the EF-111As were ever assembled. The Air Force has just ten Compass Calls, with six more coming.

"First in, last out," according to their motto, will be the Wild Weasels. They have been flying the F-4G variant of the Phantom since 1978. Weasels still carry the Shrike and can employ several other missiles, but preferred ordnance is the AGM-88A HARM, on which the Air Force is currently taking deliveries. HARM has three times the range of the Shrike, plus supersonic speed. To augment the Weasels, the Air Force is outfitting some F-16s to launch Shrikes and HARMs.

The Less-Noticed Side

Defensive electronic combat is the less-noticed side of the business, but vital to the combat pilot who looks to his radar warning set to tell him when he's being "painted" by the bad guys. Current RHAW (radar homing and warning) gear does a pretty good job of alerting the aircrews to danger and reporting the nature and bearing of the threat. These sets identify enemy equipment by scanning their stored memories for an emissions signature that matches what the receivers are picking up. Reprogramming these systems consumes time, which could be critical. Consequently, a program to provide Area Reprogramming Capability (ARC) in the field is being followed with considerable interest.

Several systems normally regarded as belonging to the domain of C^3 are quite relevant to electronic combat as well. These include the Have Quick tactical radio, whose transmitters jump to a new frequency every tenth of a second to stay ahead of enemy jammers. The Mark XV IFF (identification, friend or foe) system has finally cleared a multinational tangle of delays, and its installation in thousands of platforms will begin around 1993. It will meet a long-standing need for a better way to sort out, electronically, who's who. One of the most important aircraft in any combat theater will be the E-3 AWACS. With its antijam radar, massive tracking and data-processing power, and deep look at the air battle, the E-3 would have a profound influence on the various jammers, jammees, penetrators, interceptors, and ground-based defenders.

Good as these forces and systems are, they cannot defeat the entire electronic order of battle arrayed against them. The emitters and radar-controlled weapons are too numerous for that. The Air Force

Like the EF-111, which serves a unique purpose on deep-strike missions, the Lockheed EC-130H Compass Call aircraft serves a singular role as an enemy communications-jamming aircraft. The EC-130Hs are operated by the 41st Electronic Combat Squadron of the 552d Airborne Warning and Control Wing from Davis-Monthan AFB, Ariz.

The Northrop AGM-136A Tacit Rainbow autonomous loitering missile system is the latest tool to combat the electronic threat. Tacit Rainbow will be used as a complement to the Texas Instruments AGM-88A HARM to knock out enemy radar sites. The AGM-136A will be carried by Air Force B-52s and Navy A-6E Intruders. This picture shows the missile during initial flight testing while a Navy A-7 Corsair (right) flies chase.

would not be able to attack all of them at once, even if that were the strategy, which it isn't. The function of the electronic warriors in a European war would be to punch holes in the Soviet IADS.

The concept of taking on enemy emitters incrementally is seen, for example, in the Air Staff's current thinking about how to deal with the problem of Soviet monopulse radars. Technological responses are possible, and some countermeasures are nearing full-scale development. A pure "systems" solution, however, would be too expensive to provide for the large tactical force. New countermeasures will be employed, as feasible, along with existing countermeasures, tactics, the inherent capabilities of modern fighters, skill, and cunning. This strategy looks at the problem in a total context.

Works in Progress

• **EF-111A Upgrade.** Updates the processing and jamming subsystem of the EF-111A Raven radar-jamming aircraft. Contractor is Eaton AIL. Flight tests begin in January 1988.

• **F-4G Wild Weasel.** Only certain E-model Phantoms can be converted to F-4Gs, and available airframes are getting scarcer. USAF will buy eighteen more in 1988. A Performance Upgrade Program (PUP) is developing a new signal processor for additional memory and speed, and a new direction receiver group will add to the F-4G's capability to process and handle threats of the 1990s. Prime PUP contractor is McDonnell Douglas, with Sperry and E-Systems subcontracting.

• **ASPJ.** The Airborne Self-Protection Jammer will provide internal countermeasures for USAF's F-16 and several types of Navy aircraft. The Pentagon says the program is now on track and that test results look good. Deliveries begin in 1990. Contractors are ITT and Westinghouse.

• **INEWS.** Supposedly the wave of the future, the Integrated Electronic Warfare System will equip USAF's ATF and the Navy's ATA. A fully integrated and versatile electronics suite that pulls everything together. Two joint-venture teams: Sanders/GE and TRW/Westinghouse.

• **ECM Pods.** The older of USAF's two main ECM pods, the ALQ-119, is getting a kit upgrade, after which it will be redesignated the ALQ-184. Contractor is Raytheon. Production of the newer ALQ-131 ECM pod continues by Westinghouse.

• **EC-130H Compass Call.** The Air Force has ten of these aircraft for communications jamming and will acquire six more in 1987. Contractor is Lockheed.

• **AGM-136A Tacit Rainbow.** Joint-service ECM drone in development by Northrop. The Air Force has the lead on the air-launched version, and the Army is working on a ground-launched one.

• **Area Reprogramming Capability (ARC).** Will give theater commands the much-needed capability to reprogram electronic software locally as the threat changes. Reprogramming must currently be done Stateside.

IADS must first pick up the penetrators, then feed the information through the command and control network to the interceptors, SAMs, and guns. The interceptors and the firing batteries have to choose their targets, acquire, track, lock onto, and hit them—all while the fast-moving aircraft are within range of the weapons. This chain of events is a critical path; each function must succeed for the intercept to succeed.

"If we can break the chain at any point, we will defeat the air defenses," says a recently cleared Pentagon briefing. "However, monopulse angle tracking is employed only during radar tracking and missile guidance, and countering it is, therefore, only part of the problem we must solve. We are certainly not always compelled to attack whatever might be the strongest element of the process at a given point in time. Nor must we necessarily attack all of the segments at once. . . . This broad approach is expected not to defeat any segment of the air defense process completely, but rather to reduce its effectiveness to the point where our mission success is maximized."

Inside and Integrated

The Air Force's top procurement priority for electronic combat is self-protection equipment. Over the years, the Air Force has bought numerous specialized systems to meet

The ABCs of Electronic Combat

- **EW. Electronic Warfare.** The use of electromagnetic energy to determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum. Subsets include ECM, ECCM, and ESM.
- **ECM. Electronic Countermeasures.** Jamming and deception of enemy electronics. ECM systems include EF-111 jamming aircraft and jammers, flares, and chaff carried by individual fighters.
- **ECCM. Electronic Counter-Countermeasures.** The response to ECM. Seeks to protect one's own use of the electromagnetic spectrum and avoid radar-controlled attack by the enemy. Examples include Have Quick antijam radios.
- **ESM. Electronic Support Measures.** Use of a system's electronic signature to learn the enemy's electronic order of battle, including location and capability of his emitters. ESM systems include RF-4C TEREC aircraft.
- **SEAD. Suppression of Enemy Air Defenses.** Physical and electronic measures to neutralize, degrade, or destroy enemy radar emitters, SAM sites, and gun-laying assets. SEAD systems include F-4G Wild Weasels with AGM-88A High-Speed Antiradiation Missiles (HARMs). Also AGM-136A Tacit Rainbow drone, now in development.
- **C^3CM. Command Control and Communications Countermeasures.** Actions to deny the enemy information and to destroy or degrade his C^3 network. Includes Operations Security (OPSEC) measures and EC-130H Compass Call communications-jamming aircraft.

specific threats and now owns an extensive assortment of warning, jamming, and dispensing gear. Most of the fleet carries this equipment in external pods, which ties up weapon stations and creates drag. Nevertheless, pod mods will continue for awhile because the cost of retrofitting all of the airplanes with internal ECM is prohibitive. Aircraft of the future, however, will have internal, fully integrated countermeasures suites.

The F-15 already has internal ECM with its Tactical Electronic Warfare System (TEWS), and the Advanced Self-Protection Jammer (ASPJ) will provide it for some F-16s and several types of Navy airplanes. But the real vision of the future is the Integrated Electronic Warfare System (INEWS), which the Air Force and the Navy are developing jointly for their next generation of tactical fighters.

Whereas countermeasures have traditionally been add-ons or retrofits, INEWS will see everything built together to work together, with the electronics almost as organic to the aircraft as the engines and the airfoils. "INEWS emphasizes jointness and commonality so that parts of the system will be usable in the Army's LHX [new light helicopter family] and other Air Force systems besides ATF," says Col. George R. Winters II of the Deputate for Reconnaissance, Strike, and Electronic Warfare at USAF's Aeronautical Systems Division.

The technologies, especially VHSIC (very-high-speed integrated circuitry), that underlie INEWS may enable the United States to stretch out its lead again in the measures-countermeasures game. General Corder says that Soviet technology in electronic combat now trails the US by a year or two, with the biggest lag seen in packaging. When designers are limited in their ability to combine components in tight spaces, they are forced to make their airframes larger or resort to other ways of compensating.

Even for US designers, who lead the league in that regard, it is not easy to get countermeasures suites down to pocket size. The ASPJ program, for example, gives fighters about the same ECM capability as that in B-52 bombers. In the BUFF, this equipment weighs 700 pounds and occupies fourteen cubic feet. ASPJ does it with 300 pounds in three cubic feet. At 100 pounds per cubic foot, it's a snug fit. (By comparison, a cubic foot of solid aluminum weighs around 112 pounds.)

The Game Goes On

Between wars, the measures-countermeasures struggle continues in less violent form, with each side seeking new advantages and probing for revelations about the electronic progress of the opposition. "You don't wait to learn his capabilities and vulnerabilities in the field," Colonel Atchison says. One subset of the game, Electronic Support Measures, consists of ferreting out such information.

The Soviet Union took note in 1986 when HARM missiles fired by US airmen scored direct hits on Libyan air defenses. And Soviet use of radio-electronic combat in Afghanistan has been of tremendous interest to US intelligence. This part of the game does not stop with observation. Some of the Soviet systems of most concern to the West are based on technology stolen from the United States.

On the technology front in the cold war of measures and countermeasures, the warriors also win some and lose some. An apparent casualty—although not yet certified as a fatality—is the Precision Location Strike System (PLSS). Its role was to be deep-look detection and targeting of enemy radars. "Unfortunately, the complex task of processing and analyzing the vast number of signals picked up during fast-paced combat operations has proven to be more difficult than anticipated," the Defense Department reported to Congress earlier this year.

Most known developments are going well, though, and it's generally assumed that still more are in progress behind the cover of secrecy. Countermeasures tend to be perishable once the enemy has seen them used, so electronic warriors often keep their best tricks hidden until they can spring them with surprise at a telling moment.

Sometimes the most effective countermeasures are the simple ones, perhaps not from the world of advanced technology at all. Colonel Atchison describes such an instance where ingenuity was the answer. When the heat-seeking SA-7 missile was introduced, it gave North Vietnamese ground troops a potent weapon against aircraft.

An AC-130 gunship crew over Fire Base English in 1972 knew about the SA-7 and was ready for it. As the SA-7 rose up from the trees and homed on the airplane, one of the crewmen fired a round from a Very pistol out the rear door. Sure enough, the missile swung toward the hot-burning flare and away from the gunship, which proceeded about its business. Score one for skill and cunning, and stand by for the next move. ■