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ECCM IN NORAD

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ECCM IN NORAD

Historical Reference Paper
No. 7
15 January 1963

By
Squadron Leader Thomas Wallnutt

Directorate of Command History
Office of Information
HEADQUARTERS NORAD

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FOREWORD

One of the major deficiencies in NORAD's programmed forces, as stated in its objectives plans for 1964-1973, was "limited capabilities of the manned bomber defenses to operate in a heavy ECM environment." Thus, one of NORAD's objectives was to strengthen the system against enemy electronic countermeasures. The purpose of this paper is to trace the major programs designed to achieve this objective.

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CHAPTER I

MEETING THE ECM THREAT

THE ECM THREAT

(b)(1), (b)(3) 10 USC Section 130C

[redacted]

The Soviet Union would likely be the only nation in this decade to have the capability to make a direct attack on North America. The Soviet weapons would consist primarily of ICBM's, sub-launched missiles, and aircraft carrying free-fall and stand-off nuclear weapons. Although the Soviets would rely increasingly on ballistic missiles, they would retain a manned-bomber force to diversify the threat and provide for damage assessment and reconnaissance. They would also use bombers against small hardened and movable targets.

At present it was estimated they could put about 200 bombers over North America on two-way missions in an initial attack. They could increase the number by using medium bombers on one-way missions, but with growth in missile capability this would become less likely.

Each Soviet bomber would carry defensive Electronic Countermeasures (ECM) equipment.* In

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* It was estimated that each heavy bomber would carry 500 lbs of chaff and 3000 lbs of electronic jamming equipment, providing each bomber with 9,000 watts of radiated jamming power distributed over the operating frequencies of all NORAD radar systems (NQR for LRAPH, dated 1 Nov 1961).

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(b)(1), (b)(3) 10 USC Section 130C

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(b)(1), (b)(3) 10 USC Section 130C

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(b)(1), (b)(3) 10 USC Section 130C

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(b)(1), (b)(3) 10 USC Section 130C

Since NORAD's establishment in 1957, a great deal of progress in improving ECCM capabilities of most parts of the system had been made. Many ECCM measures had been completed, others were programmed for completion over a period of years and were gradually coming into service, and some measures were still being sought by NORAD.*

An attempt has been made to trace in the succeeding chapters, highlights of the various programs which related to NORAD's ECCM plans and requirements.

* Not covered in this paper were organizational changes designed to improve Electronic Warfare (EW) functions in NORAD. In January 1961, the responsibility for EW policy in Headquarters NORAD was transferred from DCS/Communications and Electronics to DCS/Operations. This led to the establishment, on 1 January 1962, of a new division in DCS/Operations -- Operations Electronic Warfare Division. EW functions, previously performed by Operations, Joint Training, and Environment, were now consolidated into one division. The Operations EW Division published a new policy regulation on EW, NORADR 55-33, on 7 June 1962, and NORADR 55-16 on 31 October, standardizing the handling of ECM operations throughout NORAD.

CHAPTER II

ECCM IMPROVEMENTS FOR SURVEILLANCE SYSTEM

BACKGROUND

Until the mid-fifties, relatively low priority was given to ECCM requirements in air defense. Consequently, progress was slow in developing an ECCM capability in the radar system. But at least the system was equal to the ECM threat of that period.

In fact, by 1955, the radar system had become less vulnerable to ECM and even held a slim advantage over current airborne jammers. Ground radar operators had the use of tunable magnetrons to change radar frequencies, anti-clutter circuits to eliminate or minimize jamming effectiveness, and more powerful radar beams. By changing frequencies as often as airborne operators could locate them and jam them, AC&W personnel could force enemy ECM operators literally to play follow-the-leader. The AN/CPS-6B radar, for instance, had five different frequencies built into it which could be selected by the flick of a switch, thereby forcing the enemy to chase ground radar around the frequency band.

However, developments in electronics in that period threatened to negate the current advantage of being able to tune radars rapidly. Carcinotron tubes (high-frequency oscillator tubes), that were capable of being tuned over a wide frequency range, were becoming available to the Soviets. It was estimated that rapid tuning abilities in air defense radars gave them a two to three year advantage over currently operational jammers that were limited by mechanically tuned magnetrons.

Calling attention to the vulnerability of the air defense system to the new ECM threat, in 1955, an inter-service study group, Project Lamp Light,

[redacted]

recommended establishment of a long-term program aimed at reducing vulnerability. The Lamp Light report stressed the need for new radars characterized by frequency diversity and tunability.

In the past, radar equipment had been designed with little or no ECCM capability. Anti-jamming features were developed after the basic equipment was produced and added later on a retrofit basis. Even the new radars coming into service at that time -- the FPS-20 and later the FPS-7 -- would have only the barest ECCM capability built into them.

Lamp Light's suggestion was acted upon by the Air Research and Development Command (now the Air Force Systems Command) which undertook a two-year development project known as the Frequency Diversity Program. This called for the development of six new radars (in addition to a UHF radar being developed by Lincoln Laboratories) with a frequency range from 225 mcs to 5600 mcs. These radars were to be tunable over a 30% portion of their band and were to be as invulnerable to jamming as possible.

Another wind-fall from the Lamp Light report was that by 1956, ECCM was being given more emphasis by Headquarters USAF and the Department of Defense (DOD). For example, the JCS assigned the responsibility for studying air defense ECM needs to the Weapons Systems Evaluation Group (WSEG).

The Continental Air Defense Command (CONAD)* recognized in early 1957 that the surveillance system -- composed largely of FPS-3 and CPS-6B type radars -- was extremely vulnerable to mass ECM attack. This fact of life was forcefully driven home in October 1956 and January 1957. During these two months, SAC aircraft, newly-armed with ALT-6 and ALT-8 jammers and employing random chaff drops, flew through the three defense force areas disrupting the surveillance, identification, and control capability of much of the system. They completely jammed radars, and close control intercepts were virtually eliminated.

However, tests conducted by the WSEG showed that radars modified with ECCM fixes could counter the ECM threat. But funds for ECCM modifications were slow in coming. The Air Defense Command's efforts over a 15-month period to persuade USAF to commit FY-1959 funds for modifications to existing radars bore no fruit. A great deal of reliance was being placed on implementation of the FD program to solve the ECCM problem.

PROGRAM TO MODIFY EXISTING LAND-BASED RADARS

In September 1957, the JCS asked CONAD to outline its needs in the ECCM field. Up to this time, retrofit of the radar network had been left to ADC and USAF. NORAD, which came into existence that

* CONAD, a JCS unified command, was formed in 1954. NORAD, a Canadian-U.S. integrated command, was formed in 1957. The headquarters were merged with the U.S. members of the NORAD staff serving as the CONAD staff. In the interest of accuracy in this study, the actual command taking an action is designated. Prior to 1957, it was, of course, CONAD entirely. After 1957, it was CONAD in one instance, NORAD in another. And in some cases, both commands are involved or one follows up the other.

month, stressed the need for a retrofit program to provide all possible anti-jamming devices for existing weapons and ground environment equipment.

NORAD then issued Regulation 101-2 in January 1958, which served as a guide in determining equipment, training, and personnel requirements to counter enemy ECM. Again NORAD's program called for ECCM modification to existing systems and the inclusion of ECCM features in all future equipment.

In May 1958, CINCNORAD, General Earle E. Partridge wrote USAF, again reiterating the requirement. With the possible delay in the Frequency Diversity (FD) Radar Program, he said it was essential that all programmed FPS-20's, one FPS-6 height finder at each site, and all FPS-7's be ECCM-modified. He stated that if it were not possible to divert funds to accomplish immediate modification, a phased funding program through the FY-1959 and FY-1960 buying programs should be accomplished. "I feel," he said, "that the ECM threat to the air defense system is such that any further postponements of the procurement of ECCM modifications for the current radars incurs a risk out of proportion to the cost."

Response to these pleas finally came in June 1958. USAF announced that it planned to provide all FPS-7's and those FPS-6 and FPS-20 radars that were to remain in operation, with a capability to combat the enemy ECM threat. It proposed certain ECCM modifications for the FPS-6's and FPS-20's which would be included in the FY-1959 radar program. Other new ECCM techniques for these radars were programmed for service testing in FY-1959 and were to be included in the FY-1960 modification program. Any new techniques that could not be included during production would be considered in future retrofit programs.

CONAD was still not satisfied. The following month, it wrote that if the FPS-6, FPS-7, and FPS-20 radars were to be effectively employed in the

1960-61 time period, additional funding was needed. CONAD also stated that the modifications proposed by USAF for the FPS-20 fell short of that expected. An anti-jam console for each set was needed concurrently with the other modifications to make the FPS-20 an effective ECCM radar. The FPS-6 height finder radars needed an improved antenna if the programmed tunable magnetron was to be of value. CONAD therefore submitted to USAF its proposed Class V ECCM modifications which it felt, along with ADC, were necessary to get an effective ECCM environment.*[1]

In August, USAF replied that it was in general agreement with the Class V modifications. The proposals were being processed through ARDC and Air Materiel Command (now Air Force Logistics Command) and once the most desirable configurations of each modification was determined, the program would be funded on a priority basis.

Certainly 1958 marked the turning point in NORAD's and ADC's endeavors to get favorable action by USAF to meet the ECM threat. Largely responsible for this turn of events was the unusually rapid progress made in research and development in ECCM equipment. It became apparent that certain

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* Class V ECCM modifications for the FPS-6 included: Controllable Nod Angle Including Azimuth Control, Improved Antenna, Tunable Magnetron, Video Integration, Dicke Fix, Log with FTC, Monopulse, PRF Jitter, Pulse Compression, and an AJ Control Box. For the FPS-7 CONAD wanted: Improved AJ Console, Simultaneous Dial Transmission and Duplexing, Matched Filters, Angular Power Adjustment, Pulse-to-Pulse Frequency Shift. For the FPS-20: Tunable Duplexing, including Multiple Pre-amplifiers, Cross-gating and Wave-Guide Switching, AJ Console, Improved Video Integration, Side Lobe Cancellation, including AVA, Velocity Filters, Dicke Fix, PRF Jitter, PISAB, CFAR-MTI, Improved Antenna, and Pulse-to-Pulse Frequency Shift.

modifications to existing radars would provide an ECCM capability even before the FD radars were to be installed. A new note of optimism prevailed. Heretofore, this picture had been anything but bright since SAC had proved in 1956 and 1957 that the radar network was disastrously vulnerable to modern ECM. Accordingly, a crash program to modify some of the radars with ECCM fixes and to test them was undertaken. This resulted in the WEX-VAL tests in the 37th Air Division during August to October 1958. These tests proved that ECCM modifications to existing radars were effective, which gave impetus to the ECCM retrofit program.

However, although the requirement was clearly established by the end of 1958, the next year proved to be frustrating because of delays in procuring and installing the required ECCM fixes. The competitive fixes offered by industry took time to assess and decisions on what to buy were difficult to make. It had to be assured that the fixes were not incompatible with SAGE and the problems of necessary modifications to other parts of the system had to be considered. Lastly, there was the constant problem of funding in the ECCM program -- a factor which reached critical proportions in late 1959 when the entire air defense system underwent searching scrutiny by Congress and the Pentagon.

Cuts in the FD program at that time, however, served to sharpen the need for modification of the older radars. More FPS-20's and FPS-6's would now have to be retained in the system and they would need the ECCM capability promised by the FD radar.

By the end of the year, general agreement had been reached concerning the requirements and general design characteristics of the Class V Modifications for the FPS-20, FPS-6, and Federal Aviation Agency Air Route Search Radars (ARSR's).

FPS-20 RADAR

Although the kits for the FPS-20 did not contain all improvements CONAD had requested, it was at least a step in the right direction. The Bendix Corporation was awarded an initial contract to provide 44 modification kits. Testing of the equipment started in mid-1960, but after four months the program ran into serious trouble when deficiencies were discovered in the modifications. This led to additional studies on the advisability of installing the kits in SAGE radars. The matter was finally settled in September 1961 when USAF approved the Communications and Electronics Implementation Plan for Electronic Warfare. The document specified the GPA-102 and GPA-103 modifications for the FPS-20. They were identical except the GPA-103 had the velocity filter and not the PISAB.*[2] Previously, all FPS-20 radars had been equipped with LOG-FTC, PIE, and Non-coho MTI.

FPS-6 HEIGHT FINDER

Also included in this same document were specifications for a modification known as OA-2325 for the FPS-6 height finders.** Although this modification program was underway in 1962, USAF was investigating the possibility of reorienting it to give ECCM capability to the FPS-6's that were to be included in BUIC.[3]

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* GPA-102 consisted of Diplexing, MTI (coho and non-coho), Dicke Fix, Log, and/or Logic Circuitry, PISAB, Side Lobe Cancellation, Clutter Gating, Video Integrator, AJ Console, and Cross Gating.

** OA-2325 consisted of Side Lobe Cancellation, Log, and Dicke Fix.

ARSR FAA/ADC RADARS

Early in 1960, funding was made available for Class V Modifications for five ARSR FAA/ADC joint-use radars. However, by the time the ECCM features were settled on, the cost was revised upwards and the requirement had to be resubmitted to USAF. The outcome was that in October, USAF approved ECCM features for only three joint-use radars.*

FPS-7 RADAR

As stated, CONAD also wanted the FPS-7 equipped with Class V ECCM modifications. The modification program for this radar had been approved by USAF in 1959, but it was not to start until April 1961. Also, retrofit was to begin with the tenth unit, leaving the first nine FPS-7's without an ECCM capability. However, the FPS-7 production program was cut by five to a currently programmed 30 radars. Of this number, 25 were scheduled to be modified with ECCM fixes.**

GAP-FILLER RADAR - FPS-74

In July 1958, ADC stated a requirement to USAF for ECCM features for gap-fillers. A development program was initiated in January 1959, and various fixes were tested during that year. NORAD and ADC provided assistance in determining the minimum acceptable ECCM requirements. Generally, they did

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* Side Lobe Cancellation, LOG, Dicke Fix, CFAR-MTI, and Cross Section Sensitivity.

** The FPS-7 ECCM fixes (ECP-91) were: Dicke Fix, Side Lobe Cancellation, Side Lobe Blanking, FTI, 360° Gain Reduction, Beam Deletion, LOG Video, MTI Video (coho and non-coho and clutter gating), and AJ Console.

not advocate expenditures of huge sums of money on complex circuitry since gap-fillers were solely warning radar and were unmanned.

By October 1960, USAF had established a program to modernize all existing SAGE gap-filler sites and equip all programmed SAGE gap-filler sites (a total of 182 -- 137 in the U.S. and 45 in Canada) with the AN/FPS-74. This radar would provide gap-filler sites with an ECCM capability.* At other than new sites, the existing radar (FPS-14 or FPS-18) was to be converted to the FPS-74 with ECCM modification kits.

However, the FPS-74 program was reduced in late 1961 and early 1962 because of reductions in the 416L system to provide resources for the SAGE back-up (BUIC). The program settled to 124 FPS-74's (79 for U.S. and 45 for Canada). Although this number had not changed at the end of 1962, the Canadian program was deferred for one year because of financial stringencies. Because of this, and slippages in the U.S. program, the whole gap-filler program was being re-examined in the face of diminishing emphasis on manned bomber defense.

Status of the ECCM Radar Modification Program at the end of 1962 was:[4]

	FPS-6 (Height Finders)	FPS-7 (ECP-91)	FPS-20 GPA-102	FPS-20 GPA-103	FPS-74 (Gap Fillers)	ARSR Radars (ADC/FAA Joint Use)
PROGRAMMED	135	25	29	20	124	3
INSTALLED	25	20	23	14	0	3

* FPS-74 Fixes included: Frequency programmer, Instantaneous Frequency Correlation -- CFAR, Frequency Agility, and MTI.

THE FREQUENCY DIVERSITY RADAR PROGRAM

The FD development program, which had started in 1955 (see above), was coming to a successful conclusion by the end of 1957, despite the usual funding problems. The FD radars still in the development program at this time were the FPS-24, FPS-26, FPS-27, FPS-28, and FPS-35. By the end of that year, ARDC and ADC had reached agreement to install the new radars at actual operational sites for shake-down testing. Although the ECCM capabilities of the FD radars were inherent in the designs, a somewhat lesser capability was settled for in the production program.*

ADC sent a preliminary operational plan for the FD radar program to USAF in 1957. It was approved on 10 January 1958. The following June, ADC published a final operations plan approved by both NORAD and USAF. This plan provided for FD radars to replace most of the existing radars in the U.S. and Canada -- 175 sites.[5]

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* For the FPS-24: Frequency Agility, Diplexing, Pulse Compression, Staggered PRF, Hard Limiting, Velocity-Shaped Coho MTI, DPI, Video Integration, Velocity Filter, Sector Gating in Range & Azimuth, AJ Console. For the FPS-26: Frequency Agility, LIN - LOG, Dicke Fix, PWD, Polarization Selection, IAGC, Band Width Selection, AJ Console, and 3rd Detector. For the FPS-27: Frequency Agility, Dicke Fix, Staggered PRF, LOG FTC Coho & Non-Coho, Individual Channel Blanking, Automatic RX Selection, Clutter Edge Blanking, Velocity Filter, PWD, DPI, and AJ Console. For the FPS-35: Frequency Agility, A-2 Console, Pulse Compression, Coho MTI, Variable Bandwidth, Velocity Filter, Sector Gates, Side Lobe Blanking, Azimuth Strobe Reporter, Video Integration, Dicke RX, AJ Console, LOG RX.

[redacted]

However, by the end of 1958, the FD program was fairly unstable due to budget reductions and technical problems. USAF announced that some $29 million had been dropped from the FY-1960 buying program which would reduce the FD radar procurements by 24 FPS-26's. As stated earlier, this had a bearing on the decision to proceed with modifications to the old radars.

Throughout the next three years the FD radar program underwent many changes and suffered major cuts. The FPS-28 was cancelled entirely in 1960. In 1961, because of fund limitations, USAF deferred procurement of the FPS-27 radar and the supporting construction program for FY 61-62. Later in the year, it cut out five FPS-27's and 26 FPS-26's.

In any case, in 1961 one FPS-24 and three FPS-35 FD radars were operational.

Status of the FD Radar Program at the end of 1962 was:[6]

	FPS-26 (Height Finder)	FPS-24 (Search	FPS-27 (Search	FPS-35 (Search	Total (Search)
PROGRAMMED	71	12	32	12	56
INSTALLED	35	10	0	10	20

PROGRAMS FOR OFF-SHORE RADARS

TEXAS TOWERS

The radars on both Texas Towers off the East Coast had been modified with ECCM fixes for some time. The two FPS-6 height finders on each tower were equipped with Side Lobe Cancellation, Log

Receiver, and Dicke Fix -- the same modification for the land-based FPS-6's (OA-2325).

The FPS-20A search radar on each tower was equipped with the GPA-103 ECCM modification kit.* This radar with ECCM modification was redesignated the FPS-67.[7]

AIRBORNE EARLY WARNING AND CONTROL RADARS

In November 1958, ADC submitted requests to USAF for ECCM modifications to AEW&C radars -- APS-95 Search Radar and APS-45 Height Finder. Since then, ADC had emphasized a continuing and urgent need for ECCM fixes and sought approval and funding. As matters stood, various prototype fixes were being tested, but a program to modify these radars for ECCM had not yet begun.[8]

NAVFORCONAD RADARS

The radars in the Navy radar ships and aircraft in the NORAD system had an ECCM capability as shown below:[9]

	Radar	Function	AJ Controls
AGR's	AN/SPS-8A and B	Height Finder	STC, FTC,
	AN/SPS-12	Air Search	IAVC, IAGC
	AN/SPS-17	Air Search	
DER's	AN/SPS-8A	Height Finder	STC, FTC,
	AN/SPS-5	Surface Search	IAVC, IAGC
	AN/SPS-10	Surface Search	
	AN/SPS-29	Air Search	

* GPA-103 consisted of: Diplexing, MTI (coho and non-coho), Dicke Fix, LOG, and/or Logic Circuitry, Velocity Filter, Side Lobe Cancellation, Clutter Gating, Video Integrator, AJ Console, and Cross Gating.

WF-2	AN/APS-82	AEW	STC, FTC, IAVC, IAGC
WV	AN/APS-45 AN/SPS-20	Height Finder AEW	STC, FTC, IAVC, IAGC *

PROGRAM FOR THE BALLISTIC MISSILE EARLY WARNING SYSTEM

Also vulnerable to ECM and requiring ECCM fixes were the radars of the Ballistic Missile Early Warning System. In October 1961, USAF authorized $160,000 for quick fixes to give BMEWS a limited capability to recognize when it was being jammed. These fixes were installed in Sites I and II and included a Test Target Generator, Noise Monitor, and ECM Simulator to provide operator training.[10]

A complete ECCM program for $43 million that would give BMEWS some capability to operate in an ECM environment was approved by USAF in March 1962 and sent to DOD for approval and funding. Additional fixes for recognition and analysis were an ECM Monitor and a Central Data Processor Expansion, to be used in conjunction with the Test Target Generator. Active ECCM modifications included Polarization Selection (horizontal-vertical) to provide selective blanking, and Narrow Band Frequency Shift to provide manual control over the "moon fix." Tentatively approved in the program were a Doppler Filter Display and Blanking, Wide Band Frequency Shift, and Side Lobe Cancellation.[11] However, DDR&E placed a hold order on USAF's ECCM program since the estimated cost was $52 million and had to be reduced.

A revised ECCM program for $28 million was approved in November 1962 by the Assistant

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* See Glossary.

Secretary of the Air Force (R&D). This program provided for continuation of fixes contained in the original program, but excluded production funds for the Side Lobe Canceller. Instead, funds were provided for a prototype Side Lobe Canceller with purchase of follow-on units to be held in abeyance pending evaluation of prototype tests. Also, funds for the Wide Band Frequency Shift were temporarily suspended pending completion of a study on pulse compression as a substitute item.

The revised program was submitted to DOD for approval and release of funds.[12]

[redacted]

CHAPTER III

ECCM IMPROVEMENT FOR WEAPONS SYSTEMS

PROGRAM FOR NIKE HERCULES RADARS

Included in the Nike Hercules Improvement Program, were extensive ECCM improvements to the Nike Hercules radars. Major items being added to the Hercules system were a HIPAR (High Power Acquisition Radar) and an ECCM improvement kit for the Target Tracking Radar (TTR). An ECCM kit, consisting of AJ display circuits, was also being installed in the original acquisition radars (LOPAR).

As the name implied, HIPAR was a major step forward in power output (6-7.5 megawatts) over previous acquisition radars. Significant improvement in "burn through" range was achieved in a heavy ECM environment. The ECCM features of HIPAR were an integral part of the set and were not retrofitted as in the case of other acquisition radars.*

NORAD had a requirement to equip all 139 Hercules fire units in the system with HIPAR radars. Currently, 66 HIPAR sets were funded by the Army at a cost of nearly $1,000,000 each. Those fire units not receiving HIPAR's were to get FPS-36 radars. These radars were called ABAR's (Alternate Battery Acquisition Radars).

Since the FPS-36's had little ECCM capability, a kit was being added and the radar redesignated

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* HIPAR ECCM features were: High Power Output, Narrow Azimuth Beam Width, Side Lobe Suppression, L-Band Operation (Frequency Diversity), Fast Frequency Shift Capability, Anti-Jamming Display Circuits, Random Varying PRF, Non-coherent and Coherent MTI's.

the FPS-71.* A further modification was approved to increase peak power output against ECM to five megawatts by adding amplitrons and parametric amplifiers.

The ECCM modification kits for the TTR were being installed in all 139 Hercules fire units. This included a long-pulse mode which increased the average power output by a factor of ten and improved ECCM capability. Another ECCM feature of the TTR was short-pulse transmission which improved range definition.

Frequency diversity was achieved with the addition of a Target Ranging Radar (TRR) operating in the K band. The TRR provided range information when the TTR was being jammed. An ECCM feature of the TRR was two transmitter-receiver combinations with panoramic receiver display.[1]

The photograph on the opposite page shows a group of radars at Site W-64, an ARADCOM Nike Hercules installation at Lorton, Va. In the battery control area are a LOPAR, TRR, TTR, and HIPAR (center).

ECCM FEATURES FOR MANNED INTERCEPTORS

A number of ECCM features had been installed in NORAD manned interceptors to increase the effectiveness of airborne radars operating against jamming. These features took the form of circuit fixes and home-on-jam equipment**[2] However, the

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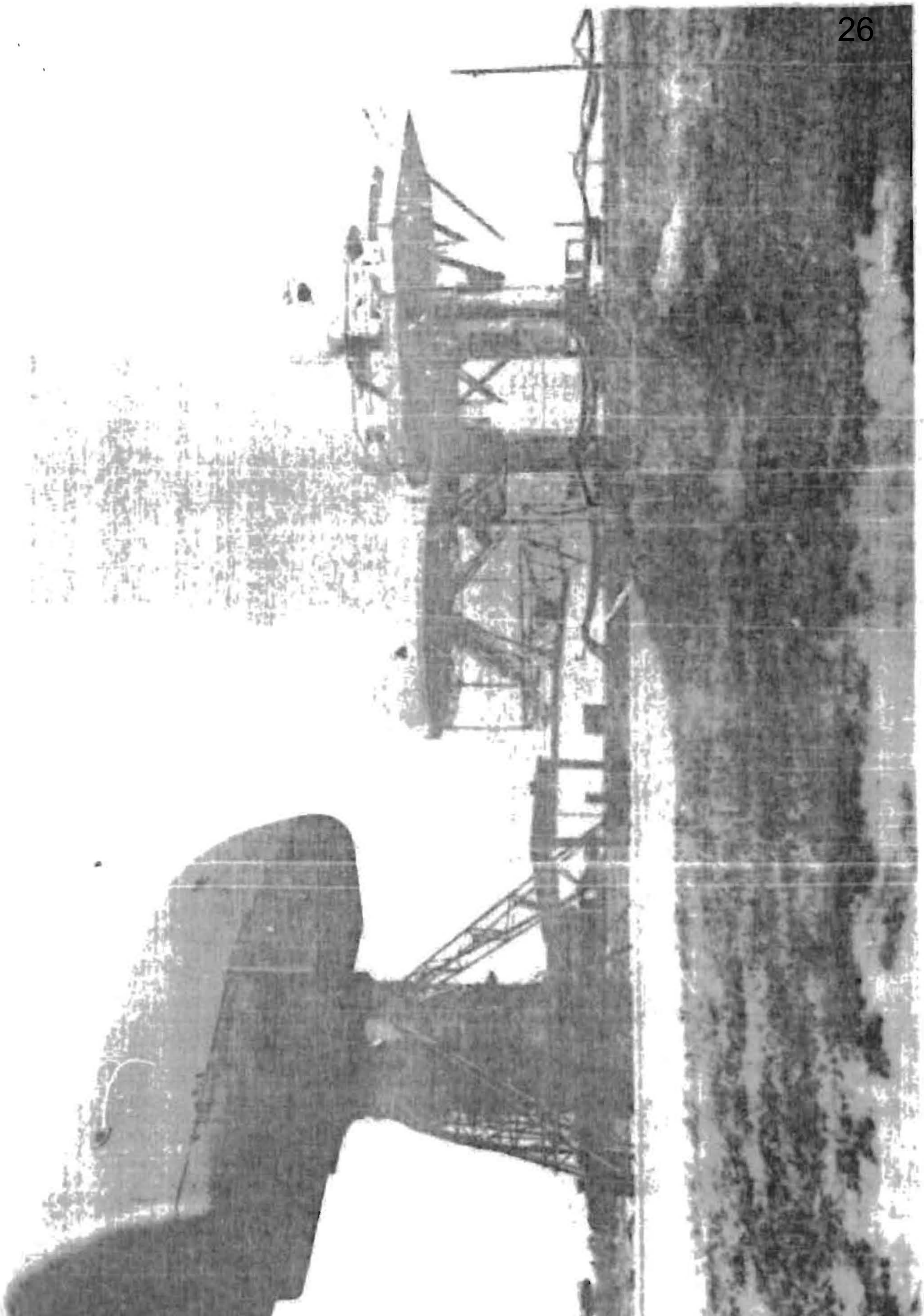
* FPS-71 ECCM features were: Narrow Azimuth Beam Width, Side Lobe Suppression, L-Band Operation (Frequency Diversity), Anti-Jamming Display Circuits, Non-coherent and Coherent MTI's.

** Current ECCM features installed in the F-101, F-102, and F-106 were: Range discrimination-anti-chaff, Automatic RF Tuning, Ferrite Attenuator, Home-on-Jamming, Rapid Relock, and Random PRF.



capability of airborne systems against ECM aimed at the airborne radars was limited by the transmitting power and circuitry which could be carried in interceptors. In the meantime, the capacity of the bomber to jam had been steadily increasing. The Soviet was now capable of jamming with one kilowatt carcinotron tubes and would likely have one kilowatt traveling wave tubes in operational quantities by the mid-sixties. Thus, the time had been reached when the present ECCM features in the interceptors were inadequate.[3]

In 1960, when USAF was forced to reduce the planned interceptor force, a compromise was made to modernize current interceptors. Accordingly, the Air Force contracted Hughes Aircraft Company to develop a number of Class V modifications which would improve primarily the ECCM capabilities of the F-101, F-102, and F-106. These modifications were: infrared search and track system, redesigned antenna with larger dish, parametric amplifiers, anti-chaff, and rapid-tuned magnetrons. All these features were for the F-101's and F-106's. The F-102's would get only the IR search and track system. These modifications were included in the program for the Long Range Airborne Passive Homing System.*

DIRECTIONAL ANTENNAS FOR WEAPONS CONTROL IN ECM ENVIRONMENT

The vulnerability of ground-to-air communications to jamming was a matter of vital concern to ADC from 1948 on. Throughout the years, ADC sought to develop measures and devices that would provide some degree of protection to the link between ground control and interceptor. For at least a decade, no single piece of equipment was developed which solved the problem. Thus, present-day manned and unmanned interceptors were still

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* See Chapter V - Passive ECCM Systems

[redacted]

vulnerable to communications jamming although they were somewhat better off in the SAGE environment controlled by Time Division Data Link (TDDL).

Moreover, TDDL was less susceptible to electronic jamming when used in conjunction with the AN/FRT-49 (20kw) high-power amplifier and/or AN/FRA-37 directional antenna. The latter provided a high-gain directional antenna array and high-power transmitter to give ECM protection. A few of the FRT-49 amplifiers had been installed at TDDL sites, but the FRA-37 program of 23 sets for U.S. and 16 sets for Canada died on the vine.

In July 1961, although ESD had reported favorably on the ECM-resistent capability of the FRA-37 directional antenna, it questioned the wisdom of implementing such a system because of the high cost (approximately $23 million) and the emphasis being placed on a SAGE back-up capability. ESD recommended that plans for procurement be canceiled. In view of the ECM threat, both NORAD and ADC were quick to disagree with the recommendation. Despite this protest, the Secretary of Defense placed a hold order on FRA-37 procurement in early August. A complete rejustification of the need for this system was requested.

ADC again directed attention to the fact that the antenna system was essential to control of air defense weapons in an ECM environment. It appeared somewhat inconsistent to provide extensive anti-jamming features for the ground radar system but not for the command and control link. ADC requested USAF to secure release of funding for the FRA-37. Although it held out little hope for success, USAF agreed to seek reinstatement of the program. Because of a DOD decision that no upgrading of SAGE was to be undertaken, USAF's effort was unsuccessful. Finally, the 416L reorientation plan of 1 November made no provision for the high-power directional antenna.

On 1 March 1962, when NORAD issued NADOP 64-73, it stated a requirement for narrow-band (15-16 db

[redacted]

gain) directional antennas for 39 selected TDDL sites to replace the $23 million FRA-37 program. It said that because of the cancellation of the FRA-37, positive control of weapons under heavy ECM conditions could not be assured. A narrow-band directional antenna system would satisfactorily correct this deficiency, however. Also, the reduction in band width and antenna gain requirements would greatly reduce the cost of the substitute antenna program and still provide sufficient "burn through" capability in a heavy ECM environment.

On 15 June, NORAD requested ADC to reinstate a directional antenna requirement program at 39 GATR sites. ADC, in turn, requested USAF to approve the requirement and fund it in the ADC package program. USAF passed the requirement to ESD for study and requested ADC to support the program only for BUIC.[4]

[redacted]

CHAPTER IV

TRAINING AGAINST ECM

SAC JOINT ECM/ECCM TRAINING

EARLY TRAINING

From the start, the air defense forces had relied on Strategic Air Command to provide most of the ECM for training. SAC's BIG PHOTO ECM program began in 1950 and lasted for six years. Although this program improved during the period, it was generally ineffective in providing the necessary ECCM training for the air defense system. SAC was occupied with its primary commitments and its ECM equipment was incapable of jamming most of the radar frequencies. What jamming SAC could do was easily countered by the ground environment.

It was not until 1956-57 that SAC was capable of providing effective jamming. At that time, SAC was being armed with multiple jammers which put the advantage squarely on the side of the attacking bomber. Since the system had nothing to counter the advances in SAC's ECM equipment, which of course represented the increased enemy threat, efforts in ECCM training were accelerated.

This led to a new series of monthly ECM exercises with SAC beginning in April 1957. While it lasted, this series provided the best training up to that time for both the U.S. and Canadian Air Defense Commands. However, although some parts of the air defense system were well exercised now, others continued to be untouched. For one thing, SAC was unable to jam effectively S-band radars operating above 3250 mcs. This precluded thorough evaluation of Army Nike unit effectiveness against ECM. Also, in November, SAC withdrew its only ECM wing from the exercises, which greatly reduced training benefits. Finally, the exercises were stopped completely in February 1958, following a collision between a SAC B-47 and an ADC F-86.

BIG BLAST PROGRAM

It was not until October 1958 that ECM exercises with SAC were resumed. Thus, for nine months the air defense system of North America received virtually no live ECCM training, and the system deteriorated. Finally, negotiations were completed and a new series, code-named BIG BLAST, got underway. This series came about largely as a result of USAF's decision in June 1958, not to build up the ADC ECM force but to exploit SAC's ECM potential. USAF held that SAC could fulfill the air defense training requirements and directed ADC and SAC to work out a program.

In Big Blast, SAC bomber wings were paired with air defense divisions. All missions were planned primarily as NORAD component ECCM training missions, and Headquarters NORAD was coordinating agency between SAC and the participating forces. The missions were designed to complete one penetration leg of at least one and one-half hours duration employing maximum ECM.[1]

The program was revised in October 1961. The U.S. and Canada were divided into three geographical air defense training areas. These areas were aligned with SAC numbered air forces. Each of the latter was to provide one exercise each month to the applicable air defense area. Each exercise was to consist of a minimum of 20 SAC aircraft using maximum ECM at specified portions of the route.[2]

Although Big Blast, which was still going at the end of 1962, had surpassed the caliber of previous ECM training with SAC, the program fell persistently short of NORAD's needs. Chronically, SAC was still able to devote only a limited amount of flying time to the exercises. Also, the frequency coverages and capabilities of SAC's ECM equipment remained largely incompatible with the NORAD system, since they were designed for use against the Soviet air defense system.[3]

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RADAR BOMB SCORING PROGRAM

Another continuing NORAD/SAC series was the Radar Bomb Scoring (RBS) Program initiated in the fall of 1960. The purpose was to provide joint ECM/ECCM training to SAC crews and ARADCOM units. It provided ARADCOM units with vital ECM operating experience against high-performance aircraft in adequate numbers. Although it started on a tentative basis, the RBS program steadily expanded in scope and importance as a joint ECM/ECCM training venture. For example, in November 1961, approximately 5600 runs were scored by Nike units.

In July 1961, NORAD concurred in a SAC proposal to establish a low-level SAC/Nike RBS program on a continuing basis. A test of the capability of Nike to score low-altitude radar bomb runs had been successfully completed earlier in July. By September, NORAD and SAC had established procedures for conduct and implementation of a permanent low-level RBS program. The program was also expanded to include Alaska, since the Nike units there were not under ARADCOM.[4]

DEEP RIVER

There were a number of terminal joint ECM/ECCM exercises, evaluations, and test projects which had provided valuable ECM experience for the NORAD system. Of note was Deep River which was the third phase of the SAGE/Missile Master integration tests.

Deep River ran during CY 1961-62 in the 26th NORAD Region and consisted of 12 missions of 30 to 40 SAC aircraft each. The purpose of Deep River was to evaluate the operational effectiveness of an integrated SAGE/Missile Master System against manned bombers employing varying degrees of ECM. The tests were conducted in two major ECM environments: an ALT-6 spot-sweep jamming environment and an L-band carcinotron barrage environment with

ALT-6 spot and/or sweep jamming in low L-band.

The conclusions of Deep River were that the SAGE system surveillance of a moderate size high altitude bomber force was: "Practically 100 percent effective in a non-ECM environment; slightly impaired in a moderate spot-sweep and chaff ECM environment (chaff is major contributor); seriously impaired in a carcinotron barrage ECM environment; further degraded when sophisticated maneuvers are employed with either spot-sweep or carcinotron jamming."[5]

SKY SHIELD

Sky Shield provided the NORAD forces with realistic ECCM training on an annual basis against a mass bomber attack employing ECM. All non-participating aircraft throughout the continent were grounded for the duration of the exercise in order to permit unrestricted use of ECM by the attacking force.

ADC ECM FORCE

In 1950, the same year SAC began joint ECM/ECCM training, a few modified B-25 aircraft with World War II jamming equipment were assigned to air defense. The force, consisting of eight aircraft, was poorly equipped and, with the inadequate performance of the B-25, added little to SAC's ECM efforts.

Finally, in 1954, ADC radar calibration squadrons were formed into radar evaluation flights and given the additional mission of providing ECM training. Seventeen B-29's, previously assigned to the radar calibration squadrons, were added to the eight B-25's. However, the B-29's contributed little ECM training because of delays in modifying them. They had only locally-installed chaff dispersers and, in a few cases, S-band jammers. It was not until 1956 that the B-29's were finally modified to carry ECM gear.

In anticipation that the ECM-modified B-29's would not provide realistic training, in October 1954, ADC asked for B-57's with a configuration especially designed for ECM training. USAF approved the need and took steps to develop the aircraft, but nothing materialized despite ADC's continued promptings.

NORAD, not long after its formation in 1957, joined ADC in its pleas to USAF for more modern ECM aircraft. NORAD said that its ECCM training requirements could not be met by any command or combination of commands in existence. The SAC training missions and the ADC radar flights were valuable, but they failed to satisfy NORAD's needs in quality or quantity. Nevertheless, in June 1958, USAF declared that it would not build up the ADC ECM force and directed greater use of SAC's ECM potential.

By early 1959, it became apparent that despite efforts to increase SAC's participation in air defense training through the Big Blast program, ECCM training remained woefully inadequate. This spurred ADC once again to apply to USAF for a high-performance ECM aircraft to replace the B-29. ADC asked for 75 B-57 aircraft, equipped with universal jamming pods and external chaff dispensers.[6]

On 20 March 1959, General Partridge, CINCNORAD, wrote to General White, Chief of Staff, USAF, giving "wholehearted" support to the B-57 requirement. He emphasized that with present ECCM training, in an emergency not more than half the effectiveness of the air defense system could be achieved.[7]

Finally, in April 1959, USAF assigned 50 B-57 aircraft -- 25 less than the number asked for. The B-29's were to be phased out and the ECM equipment transferred to the B-57's.[8]

By the end of 1960, the B-57's had been transferred to the two ADC radar evaluation squadrons. The following year, a modification program was begun to fit a number of these aircraft with internally-installed ECM equipment. Sixteen aircraft in each squadron were fitted with one ALT-6 with X-, S-, and L-band oscillators.

Early in 1962, USAF approved and funded a program to equip the B-57's with three-phase engine-driven 20 KVA constant-speed alternators and wiring. Each aircraft would then have sufficient power to supply ten transmitting systems for jamming. Current planning called for the 32 aircraft in the radar evaluation squadrons to be modified to include in each aircraft five ALT-6's, three ALT-13's, and two ALR-18's. This configuration would provide an ECM capability against all NORAD's major frequency bands. In addition, twelve B-57's at Biggs AFB were to be modified to give them an ECM capability against Nike radars.[9]

AIRBORNE ELECTRONIC JAMMING SYSTEM

Despite improvements in ADC's ECM force and in joint SAC/NORAD training programs, NORAD's requirement to make the system effective against the ECM threat was still far from satisfied as matters stood in the early sixties. NORAD needed an airborne electronic jamming system under its operational control that could provide effective ECM against its ten major frequency bands in the manned bomber system.*

Generated by this need, a new concept in airborne ECM was developed -- a self-contained detachable pod, containing interchangeable electronic jamming units, which could be slung externally on any aircraft in the air defense inventory. Recent developments in electronic tubes had made it feasible to package ECM equipment of sufficient power-output in a detachable pod.

This requirement was set out in the NORAD Qualitative Requirement for Airborne Electronic Jamming System, dated 1 June 1961.[10] This NQR called for a family of ECM pods capable of providing effective ECM against all ten NORAD frequency bands.

NORAD envisaged 16 ECM pods allocated to each of the 43 NORAD interceptor squadrons and 50 pods to each of the two B-57 squadrons. This allocation would provide the required electronic jamming capability for any air defense exercise regardless of geographical area or number of aircraft involved.

In follow-up action to the NQR, ADC submitted a Qualitative Operational Requirement to USAF on 8

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*

NORAD Band No.	Band (in mcs)	Type of NORAD Radar	Type of ECM
1	214-236	Picket Ship & SAGE Search	Hi pwrd barrage
2	400-500	Doppler, AEW & SAGE Search	" " "
3	1215-1365	SAGE & Picket Ship Search	" " "
4	1350-1450	Nike HIPAR	" " "
5	2320-2680	SAGE Search	" " "
6	2700-2900	SAGE Ht Find & Gap Filler	" " "
7	3100-3570	Nike LOPAR & Picket Ship-Ht Finder	" " "
8	5400-5900	SAGE Ht Finder & Picket Ship Search	" " "
9	8500-9600	Nike TTR & AI	To be determined
10	15500-17500	Nike TRR	To be determined

November 1961.

On 24 March 1962, USAF advised NORAD and ADC that it "recognizes the world wide deficiencies in air defense system ECM training capabilities which preclude exercise of possessed ECCM equipments on a frequent and regular basis." To alleviate this situation, USAF said, an Operational Support Requirement (OSR) for air defense ECM training equipment was being prepared. Its purpose was to align developmental effort with training requirements on a priority basis and to provide a single reference source to document and control future requirements.

To this end, USAF was realigning current ECM modification programs. A program to modify the century-series aircraft and T-33's with the ALQ-31 ECM Training Pod was cancelled. A program to equip ADC, Alaskan Air Command, and Pacific Air Forces B-57 ECM target force aircraft with three-phase engine-driven 20 KVA constant speed alternators and wiring was approved and funded. Finally, 300 QRC-160 X-, S-, and L-band training pods for ADC, AAC, PACAF, U.S. Air Forces in Europe, and Air Training Command were to be funded by USAF to provide initial minimum squadron training capability. For purposes of uniform worldwide distribution, allotments were to be made according to UE squadron strengths. USAF said this would provide ADC and AAC with 260 QRC-160 jamming pods.[11]

The proposed USAF OSR for air defense ECM training equipment was passed to NORAD in June for review and comment. NORAD generally concurred in the OSR but made a number of recommendations to USAF to bring it in line with the NQR for ECM pods. Currently, the OSR was being staffed for publication at Headquarters USAF.

In the meantime, USAF had emphasized that because of limited funds, it would have to procure ECM pods in yearly increments. Approximately $6 million would be available for FY 1963, USAF advised in November.[12] This would buy 131 QRC-160 pods -- 123 for ADC and 8 for AAC. They would provide an ECM capability in four of NORAD's ten frequency bands* -- a start towards satisfying the ECM pod requirement.

Finally, in connection with the ECM pod program, USAF authorized $50,000 of FY 1962 funds to evaluate a proposed mono-pulse Melpar X-band automatic jamming technique. NORAD had recommended procurement for investigation, under the QRC program, of certain items of equipment to fulfill its ECM pod requirement. The Melpar funding satisfied one of NORAD's requests.

This proposed system, if effective, would have a number of advantages over existing ECM techniques; e.g., it would require only a simple ECM receiver, and jamming would be done on frequencies separated from those transmitted by the radar. It would be applicable to NORAD's pod requirement against mono-pulse tracking radars and have broad application to various weapons systems against a wide variety of threats.[13]

* Band 3 1215-1365 mcs - SAGE & Picket Ship Search;
Band 4 1350-1450 mcs - Nike HIPAR;
Band 6 2700-2900 mcs - SAGE Ht Finder & Gap Filler;
Band 9 8500-9600 mcs - AI

[redacted]

CHAPTER V

PASSIVE ECCM SYSTEMS

(b)(1), (b)(3) 10 USC Section 130C

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least temporarily, further experimentation with passive detection equipment.

But the following year interest was revived. A requirement for a passive detection system as part of the active radar network was stated by ADC in June 1956. Four years later, two ground-based systems -- JAMTRACK and AN/TLQ-8 -- were available for testing.

USAF budgeted for development and production of the TLQ-8 in FY 1961-62. However, by January 1961, the TLQ-8, as then designed, was not recommended because of its low capability and the need for costly custom installation at each site. Instead, it was proposed that a third technique -- a system known as TCU/ASTRA -- be tested. This Threshold Control Unit/Automatic Strobe Tracking was basically an anti-jam type of display controlled by an operator. The SAGE 416L Project Office recommended implementation of this system in SAGE by mid-1962.

ADC and NORAD, however, recommended that an improved version of the TLQ-8 be developed as the primary passive defense system. The Project Office agreed that the TLQ-8 was the only system, with extensive modifications, that possessed the potential to meet NORAD/ADC requirements. Nevertheless, the Project Office continued to recommend the TCU/ASTRA and based its position on a high degree of technical confidence, the earlier capability this system could provide, and an overwhelming cost advantage over the TLQ-8.

Following comparative studies requested by USAF, a final test report was prepared by the Project Office in May 1961. Again, TCU/ASTRA was recommended along with development of a more sophisticated system for ultimate use. A modified version of the TLQ-8 was suggested with retention of the TCU/ASTRA as a back-up system.

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parametric amplifiers and rapid tuning (pulse-to-pulse frequency shifting).

USAF was also taking separate action to provide funds for an LRAPH System development for the BOMARC B missile.[5] However, NORAD was not optimistic about getting it because of the high costs and technical problems involved in modifying the BOMARC system.*[6]

* Doppler characteristics of the BOMARC system currently gave it a limited ECCM capability.

CHAPTER VI

CANADIAN ECCM PROGRAM

RESEARCH AND DEVELOPMENT

With the formation of the Air Defence Group in December 1948 and the building of the Pinetree Radar Line, the RCAF recognized the ECM threat to the Canadian ground environment. To meet this threat, the RCAF embarked on an Electronic Warfare (EW) program of research and development, procurement of improved and new equipment, and training.

In Canada, EW R&D was coordinated and directed by the NAPKIN* Committee which consisted of representatives of the three Services, Defence Research Board (DRB), and National Research Council (NRC). The NAPKIN Committee was formed in 1956 to provide a quick reaction capability in this field, comparable to the QRC program in the U.S. Most basic R&D undertaken by this Committee was done by the NRC and DRB. However, where interests were specialized, the RCAF normally directed its own program with assistance provided by the Committee. EW developments in the U.S. and U.K. were closely monitored by the Committee to determine possible applications in the Canadian systems and to avoid duplication of development effort.

To achieve the best possible ECCM program for the NORAD environment, USAF ESD and the Directorate of EW of RCAF Headquarters formed a Joint USAF/RCAF ECCM Evaluation Group. This Group was established in August 1959. Its function was to examine and select ECCM equipments that were compatible for use on the U.S. and Canadian-financed radars in Canada.[1]

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* Code name.

ECCM IMPROVEMENTS FOR GROUND ENVIRONMENT

A program to improve the capability of Canadian-financed radars against an ECM attack began in 1957. ECCM fixes were developed, or were under development, for the FPS-507 Height Finders and FPS-508 Search Radars.

FPS-507 HEIGHT FINDERS

Receiver Group (OA5033) was developed to provide an ECCM facility for the FPS-507. It comprised a Dicke Receiver for use against barrage jamming, a Log Receiver for use against spot jamming, a PRF jitter kit for use against repeater jamming, a Pre-Selection Cavity for image rejection, and a Wide-band Pre-Amplifier. Installation of this receiver group was completed at Canadian-financed sites in December 1961.

Also, a program began in November 1957 to develop an AJ Console (OA5049) for the FPS-507. The purpose of the Console was to monitor simultaneously a maximum of three videos from the height finder radar for performance comparison and to centralize control of ECCM facilities. Deliveries were to be completed in early 1963 for all FPS-507 height finders.

A video improvement circuit (Video Enhancer) was developed in 1962 and was currently under evaluation for the FPS-507. It provided a short pulse suppressor to reduce RHI ECM noise clutter.

Finally, a Long Pulse Suppressor was undergoing evaluation for installation in the FPS-507. It was a clutter eliminator circuit employing video cancellation. It was designed to operate on any pulse which was longer than the radar pulse width.

FPS-508 SEARCH RADARS

An AJ Console (OA5038) was also developed for the FPS-508A Search Radar. Like the Console for the FPS-507, it was developed to monitor radar performance and centralize control of ECCM facilities. Installations were completed in November 1962.

Development of a Receiver Group (OA5035) was completed in 1962 for this radar. It consisted of a narrow band Dicke Receiver having a two megacycles IF bandwidth, a hard limiter and MTI CFAR IF output in addition to its CFAR video output. It was to be installed in cascade with the already-installed wideband Dicke Receiver (OA5034). Delivery was expected in early 1963.

Lastly, a Duplex Gating Unit was developed in 1962 to provide a capability for automatically choosing the output of the least-jammed channel of a duplexed radar. Currently under evaluation, it was planned for use with the FPS-508.[2]

PASSIVE ECCM SYSTEMS

GROUND BASED PASSIVE SYSTEMS

(b)(1), (b)(3) 10 USC Section 130C

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(b)(1), (b)(3) 10 USC Section 130C

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ECCM TRAINING FACILITIES

EARLY ECM EQUIPMENT

To train radar operators in the use of anti-jamming techniques, a requirement was established in July 1951 to fit an aircraft with ECM equipment. The first ECM aircraft in the RCAF was a Dakota, equipped with chaff dispensers and AN/APR-9 receivers. In 1956, the first C-119 was equipped with various ECM prototype equipment. The same year, a CF-100 was equipped with an ALT-4 jammer and an APR-9 receiver for training aircrew in countering electronic jamming. Two more C-119's were added in 1957, and all three were equipped with APA-74 pulse analyzers, APS-54 receivers, ALT-4 X-band jammers, and ALT-8 S-band jammers.

To supplement airborne ECM training in RCAF ADC, two mobile ground vehicles were fitted with L-, S-, and X-band intercept receivers, L- and S-band D/F units, pulse analyzers, VHF communications equipment, wideband crystal video intercept receiver with D/F units, and L- and S-band jammers.

The AN/ALT-501 L- and S-band carcinotron barrage jammer was developed and put into operation in the RCAF in 1957. This became the first carcinotron jammer in the NCPAD system. It was capable of providing spot, barrage and sweep jamming at high output powers and was electronically tunable. In 1959, improved models of the ALT-501 were installed in the C-119 aircraft. Finally, a third generation of this jammer was developed, evaluated and approved as a pre-production prototype in 1961. This jammer was a pressurized, miniaturized, high-altitude version of the previous model. The L-band version had a power output of 500-1000 watts and frequency range of 1200-1500 mcs; the S-band version had 200-500 watts power output and 2600-3400 mcs frequency range.[6]

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ELECTRONIC WARFARE UNIT ESTABLISHED

The RCAF ADC made maximum use of outside friendly forces to provide ECCM training. SAC aircraft overflying Canadian territory on training missions provided ECM. However, SAC's equipment was designed to jam the Russian radar system, and since it was understandably reluctant to "show its hand," SAC operated its ECM on a limited scale. Also, USAF ADC's ECM force made only a negligible contribution to RCAF training. Similarly, RAF bomber overflights provided only token ECCM training.

Because of this, an Electronic Warfare Unit (EWU) was established in RCAF ADC to provide an ECM/ECCM facility within the Canadian air defense environment. It began operations on 1 April 1959. The next step was to re-equip the EWU with improved jamming equipment and to increase the number of ECM aircraft to provide adequate exercise and training for the air defense system.

Providing aircraft and equipment for the ADC EWU was divided into three phases. Phase I covered the existing facilities the RCAF had at that time -- three C-119's, one CF-100, and one mobile unit. Phase II covered the addition of seven CF-100's fitted with ALT-4 X-band jammers, APR-9B receivers, and MX900/A chaff dispensers. This phase was completed. Phase III would increase the UE of ECM CF-100 aircraft to 15, and was scheduled to start in September 1963. All aircraft were to be fitted with ALT-501 L- and S-band carcinotron jammers, plus ALT-6B/ALR-18 X-band jammer installation.

Finally, a program was under way to extend the frequency range of the ALT-501 carcinotron jammer from L- and high S-bands to C- and low S-bands to cover the new FPS-26 and FPS-27 FD radars. The required carcinotrons were to be available in early 1963 and operational jammers by late 1964.[7]

[redacted]

GLOSSARY OF ABBREVIATIONS

AI	Airborne Interception
AJ	Anti-Jam(ming)
ARSR	Air Route Search Radar
AVA	Amplitude Versus Azimuth
AVNL	Automatic Video Noise Leveler
CFAR	Constant False Alarm Rate
Coho	Coherent Oscillator
CW	Continuous Wave
D/F	Direction Finding
DPI	Detected Pulse Interference
ECCM	Electronic Counter Counter Measures
ECM	Electronic Countermeasures
EW	Electronic Warfare
EWU	Electronic Warfare Unit
FD	Frequency Diversity
FTC	Fast Time Constant
FTI	Frequency Time Intensity
HIPAR	High Power Acquisition Radar
IAGC	Instantaneous Automatic Gain Control
IAVC	Instantaneous Automatic Volume Control
IF	Instantaneous Frequency
IFC	Instantaneous Frequency Correlation
IR	Infrared
KVA	Kilovolt Ampere
LOG	Logarithmic Receiver
LOPAR	Low Power Acquisition Radar
LRAPHS	Long Range Airborne Passive Homing System
MTI	Moving Target Indicator
Non-Coho	Non-coherent Oscillator

PIE	Pulse Interference Eliminator
PISAB	Pulse Interference Separation and Blanking
PPI	Plan Position Indicator
PRF	Pulse Recurrence Frequency
PWD	Pulse Width Discriminator
QRC	Quick Reaction Capability
RBS	Radar Bomb Scoring
RF	Radio Frequency
RHI	Range Height Indicator
RX	Receiver
SLB	Side Lobe Blanking
SLC	Side Lobe Cancellation
STC	Sensitivity Time Control
TCU/ASTRA	Threshold Control Unit/Automatic Strobe Tracking
TDDL	Time Division Data Link
TRR	Target Ranging Radar
TTR	Target Tracking Radar
UHF	Ultra High Frequency
VTM	Voltage Tuned Magnetron

GLOSSARY OF TERMS

Active ECM - Countermeasures which rely on the radiation or re-radiation of electromagnetic energy for their effect, and are, therefore, detectable by the enemy. They include jamming, deception, and chaff.

Amplitude versus Azimuth (AVA) [redacted] -

(b)(1), (b)(3) 10 USC Section 130C

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Anti-Chaff Receiver - The anti-chaff receiver is essentially a device capable of discriminating between targets moving at different velocities and eliminating the slower. This is usually achieved by using the chaff echoes as a reference and using a phase detector and limiter to eliminate the chaff.

Anti-Jamming Console - A console where the displays and controls of ECCM devices and displays of raw radar video are gathered for centralized control by the ECCM officer.

Automatic Video Limited (AVL) - A feature which provides automatic gain control in the receiver preamplifier to reduce the effects of undesirable signals of relatively long duration or of a CW nature. It is useful for increasing the ECM level at which a receiver will saturate.

Automatic Video Noise Leveler (AVNL) - The AVNL system samples the receiver output noise level at the end of each sweep, and automatically adjusts the preamplifier gain for the following sweep to hold the average noise level at the PPI constant, to obtain a constant false alarm rate.

Azimuth-Time Recorder - [redacted]

(b)(1), (b)(3) 10 USC Section 130C

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Carcinotron - This is a backward-wave oscillator tube but is more commonly known by its French trade name "Carcinotron." It is voltage tunable over an octave of frequency and has made wide band barrage jamming possible with equipments of conventional size. In action, it is actually a very high speed sweep jammer but the sweep frequency can be raised to 5 mcs or more making the general appearance at the radar equivalent to barrage jamming.

Clutter-Gated Noncoherent Moving Target Indicator (MTI) - Provides clutter-gating, noncoherent MTI in order that the most desirable signal processing may be used in clutter, chaff and nonclutter regions. In the case where the signal is wider than the pulse width of the radar, the clutter gate uses this signal as the reference signal against which the moving target is beat, and only the moving target is presented. In regions of chaff, the chaff becomes the reference signal and the moving target is displayed. In areas where no clutter exists, normal video is presented.

Clutter Gating - Provides for removal of clutter and chaff clouds from normal video on the basis of pulse width, and substitution of MTI video in the regions of clutter and chaff clouds.

Coherent MTI - This unit is used to discriminate between moving targets and fixed targets, and to present only the moving ones. The velocity shaping is provided to increase the subclutter visibility (30db) in the presence of scanning and clutter modulation.

Constant False Alarm Rate (CFAR) - A term applied to any radar receiver (Log, Dicke Fix, MTI, etc.) that does not exhibit a change of signal to noise ratio as a result of the changing amplitude of interfering or jamming signals. The false alarm rate is a function of the excessive noise which would be processed by the AN/FST-2 as a result of a reduced signal to noise ratio in the presence of jamming or other interference.

Cross Gating (Logic Circuits) - The cross-gating circuit is part of the composite radar receiver. It is, in effect, a small computer which automatically selects the best of a number of video outputs and processes them before they are fed to the displays.

Dicke Fix - This receiver fix is effective as a CFAR (Constant False Alarm Rate) device against periodically recurring ECM such as pulse or sweep jamming. It consists of: a wide-band filter with an impulse response which prevents the ECM recurrence from ringing the receiver; a band limiter which limits all received energy down to the noise level, but still preserves phase information; and a narrow-band filter of optimum bandwidth for the radar pulse width to discriminate against the ECM content of the limited signal. The Dicke Fix receiver, together with the log receiver, sends its output to the cross gating circuits.

Diplex-Receiver - The function of this equipment is to make the maximum use of the dual channel feature of a radar (e.g. AW/FPS-20), permitting simultaneous or time-staggered transmission and reception of two frequencies by the same antenna. Basic diplexing is enhanced by adding receiver fixes to each channel and then applying cross-correlation or logic circuitry between channels to select and pass the optimum output.

Electronic Countermeasures - That major subdivision of EW involving actions taken to prevent or reduce the effectiveness of enemy equipment and tactics employing or affected by electromagnetic radiations. ECM includes active and passive measures.

Electronic Counter-Countermeasures [redacted]

(b)(1), (b)(3) 10 USC Section 130C

Electronic Warfare - That division of the military use of electronics involving actions taken to prevent or reduce an enemy's effective use of radiated electromagnetic energy, and actions taken to insure our own effective use of radiated electromagnetic energy. EW includes ECM and ECCM.

Fast Time Constant (FTC) - Type of coupling circuit used in radar receivers to permit discriminating against echo pulses of duration longer than the transmitted pulse.

Frequency Agility - The ability to rapidly change radar frequencies within a given band either by manual selection or by automatic selection in discrete or random steps.

Frequency Diversity (FD) - A method of transmission and/or reception using a number of frequencies simultaneously to improve the tracking probability and make more difficult efforts to deliberately jam or interfere with the radar. This is accomplished by placing radar sets operating in different frequency bands at adjacent sites to complicate the jamming problem.

Homing - The act of using a receiver with directional antennas to locate and steer towards a source of radiation.

Instantaneous Automatic Gain Control (IAGC) - A very fast operating gain control used to decrease the gain of an IF amplifier to prevent overloading.

Jamming - The deliberate radiation or re-radiation of electromagnetic energy with the object of impairing the use of electronic devices by the enemy. It includes electronic and mechanical jamming.

Jamming, Barrage - The jamming of a wide portion or band of the electromagnetic spectrum.

Jamming, Spot - The jamming of a specific frequency or channel.

Jamming, Sweep - The jamming of a band of frequencies by varying the frequency of the jammer at a given rate.

Logarithmic Receiver - A nonsaturable, nonlinear receiving system. This receiver consists of a series of IF amplifiers (each capable of acting as amplitude detectors) which amplify on a logarithmic curve to maintain an essentially constant output amplitude regardless of the amplitude of the input signal. This is accomplished by successively dropping stages of amplification as the input signal increases in amplitude. As stages are dropped, the preceding stage acts as the video detector.

Long Pulse Suppressor - A video cancellation circuit which operates on any pulse which is longer than the radar pulse width. Recently developed by NRC (Canada) as a clutter eliminator and anti-chaff device.

Monopulse - An antenna technique employing two feeds and one reflector which produces two antenna beams with a small angular displacement between them. Generally used in fire control radar.

Noncoherent MTI - A wide-band amplifier and phase detector differing from a coherent MTI system in that the fixed coherent reference signal is not utilized. The slow-moving of fixed permanent echoes, chaff or weather returns are used as a substitute for the coherent signal. The phase difference between the fast-moving targets and the background returns makes possible the detection of fast-moving objects and cancellation of fixed or slow-moving returns.

Omnidirectional Antenna - A nondirectional antenna which is horizontally or vertically polarized. It is used for ECCM purposes with side-lobe blanking (SLB), side-lobe cancellation (SLC) and the panoramic or frequency time intensity (FTI) display.

"OR" Logic - Circuits that pass one signal from either of two sources and are peak selective.

Panoramic Display - A wide band display which indicates the presence of all signals within a designated frequency spectrum usually that of the radar with which it is operating. In most instances, the radar operating frequency is also indicated on the display.

Panoramic Receiver A receiver that continually sweeps through a selected portion of the frequency spectrum and, in conjunction with the panoramic display, indicates frequency of all signals present.

Passive ECM - [redacted]

(b)(1), (b)(3) 10 USC Section 130C

Polarization Diversity - This technique involves the variation of polarization such as horizontal, vertical, cross-polarization, circular or elliptical for radar use, either simultaneously or singly. The use of various polarizations will in many instances result in a reduction of effective jamming power at the radar antenna terminals, enabling more reliable radar operation in an ECM environment.

Pre-selection Cavity - By the use of tuned cavities accepting only the frequency bandwidth usable by the radar receiver, noise entering the antenna at the radar image frequency is rejected. Consequently, the amount of unwanted energy into the receiver is reduced. Since the jamming is usually uncorrelated noise, the improvement could be as much as 10 db.

Pulse Interference Eliminator (PIE) - A variable band-width receiver employing band pass filters for the purpose of eliminating side-band frequencies. It is not compatible with SAGE due to excessive delays and pulse stretching.

Pulse Interference, Suppression, and Blanking (PISAB) - Cancels asynchronous pulses by delaying the video pulse for one PRF period and comparing this with an undelayed pulse. If the pulses are synchronous, they will cancel and no blanking pulse is developed. Asynchronous pulses which are not likely to be coincident will not cancel. These pulses are amplified and used to develop a PISAB gating pulse and are applied to the transfer gates. The PISAB gating pulse functions as a blanking pulse by changing the "OR" logic to "AND" logic and does not allow video to pass through the transfer gates.

Pulse Repetition Frequency (PRF) Jitter/Diversity - The technique of varying the PRF at a random or programmed rate. Random variations of PRF will deny MTI but is effective against repeater or range gate stealers. Programmed variations are effective in eliminating blind speeds normally associated with MTI.

Pulse-to-Pulse Frequency Shift - By altering the radiated frequency in a quasi-random fashion between pulses, a radar can be protected against spot and repeater jamming. The effectiveness will depend on the bandwidth over which the change of frequency is spread.

Pulse Width Discrimination (PWD) - A circuit which eliminates or blanks received signals which are less than or more than certain predetermined pulse widths in respect to the transmitted pulse width of the radar. The PWD circuit is also used for the generation of the MTI clutter-gate.

Rapidly Tunable Transmitter - This transmitter requires broad-band RF components. It will be possible to jump frequencies on a pulse-to-pulse basis within the operating band of the radar. Pulse-to-pulse frequency agility will allow the radar to counter the threat of higher ECM power since it will force a jammer to spread its power over a wider spectrum, and will deny the uses of spoofer or repeater ECM that does not have a pulse-to-pulse ferret and lock-on capability.

Sector or 360-Degree Gain Reduction - A feature which enables the receiver gain to be reduced in a selected sector or throughout 360° to reduce the effects of heavy interference or jamming.

Sensitivity Time Control (STC) - A radar circuit which reduces receiver sensitivity for the first few thousand yards of each sweep, then gradually restores it to normal for the purpose of reducing the scope "blooming" effects of close-in echoes.

Short Pulse Suppressor - This video improvement circuit is based on the discrimination of short pulses. The short pulse discrimination technique allows immediate response to all video signals, thus is compatible with SAGE.

Side Lobe Blanking (SLB) - Uses an omni antenna and receiver to compare the relative intensities of the main antenna beam and omnidirectional antenna signals. Signals received by the omni antenna and exceeding predetermined levels are used to develop gain reducing pulses for the main lobe video.

Side Lobe Cancellation (SLC) - Utilizes an omnidirectional antenna and receiver for comparison with the signals received by the main lobe antenna. Received signals from the omni antenna and associated circuitry are compared with the main lobe returns. The omni antenna signals are detected opposite in polarity from the main lobe and the resultant output of the main lobe receiver is the algebraic sum of the two figures.

Staggered PRF Unit - This unit will extend the first MTI blind speed into the supersonic region. It is also used to optimize the velocity response over any desired velocity range. It has AJ capabilities against synchronous spoofer-type, pulse-jamming signals.

Traveling Wave Tube - A broad band microwave tube in which amplification is effected at discreet frequencies by the interaction between the field of a wave propagated along a waveguide, and a beam of electrons traveling with the wave.

Variable Band-width - The ability to vary the band pass of a circuit or amplifier. This feature is utilized to reject or reduce the effects of unwanted signals which require widerband pass than the wanted signals.

Velocity Filter (Storage Tube) - A storage tube device similar to the storage tube clutter gate which blanks all targets that do not move more than one resolution cell in less than a predetermined number of antenna scans. This device is sensitive to absolute velocity and therefore is very effective against spot bundle chaff drops.

Video Integration - By the use of suitable delay and integration circuits, the video outputs from the radar can be integrated over a number of pulse intervals. Target responses which are coherent will as a result be enhanced while random pulses and noise will be reduced by comparison.

[redacted]

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