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EFFICIENCY ANALYSIS OF AIRBORNE ELECTRONIC  
COUNTERMEASURES (ECM) SYSTEMS(U) FOREIGN TECHNOLOGY DIV  
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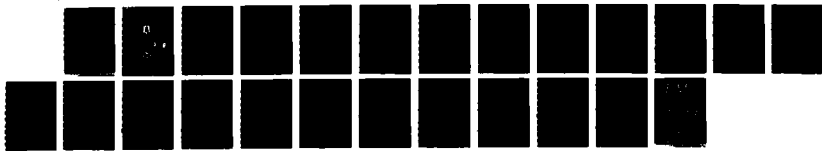
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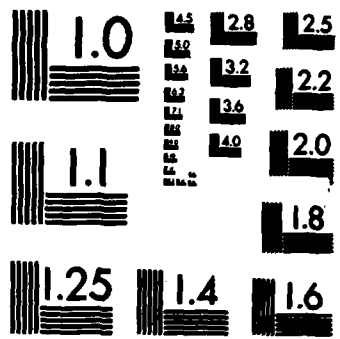
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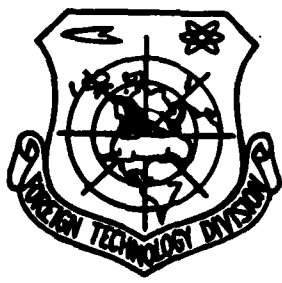
FOREIGN TECHNOLOGY DIVISION



EFFICIENCY ANALYSIS OF AIRBORNE ELECTRONIC COUNTERMEASURES (ECM) SYSTEMS

by  
Zhang Yiting

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# HUMAN TRANSLATION

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## SUMMARY

Along with the development of electronic countermeasures, the evaluation of the efficiency of airborne electronic countermeasure systems has become a question to which people have paid greater and greater attention. This article initially makes an analysis of the importance of the evaluation of efficiency and then proceeds to carry out an analysis and calculations making use of methods from operations research. It also makes use of methods relating to queuing theory in order to solve for airborne platform penetration probability and survival probability. Using the methods of game theory, it makes an analysis of the effects of the means of application of electronic countermeasures on systems efficiency. Finally, through the analysis of an electronic countermeasures combat situation, it presents a method for the calculation of airborne platform utilization factors.

### I. Introduction

(CHINESE TRANSLATION)

When the operational aircraft of military aviators are carrying out tactical missions, they receive many types of threats coming from the air and from the surface of the ground. For the most part, these threats come from various types of enemy ground and airborne weapons systems controlled by radar or internal guidance. Through the use of airborne electronic countermeasures systems, it is possible to effectively deal with radar controlled and internally guided systems. As a result, the weapons lose their control and the survival capabilities for the activities of operational aircraft in combat areas are greatly increased. This has already been proven by the experience of several localized conflicts since the 1960s. Therefore, in spite of the fact that airborne electronic countermeasures systems have become more and more complicated, their cost has also become more and more expensive. At the present time, it already occupies approximately 10-15% of the total price of operational aircraft. However, the U.S., the U.S.S.R. and the NATO countries have already

mounted electronic countermeasures systems on almost all their operational aircraft to say nothing of the fact that the air forces of third world countries are also vigorously developing airborne electronic countermeasures equipment.

The cost of airborne electronic countermeasures systems has indeed come to have many important effects, raising the cost effectiveness ratios of operational aircraft, which is the same thing as saying that the question of how to analyze the combat effectiveness of these systems has become a problem attracting the universal interest of military personnel at various levels as well as that of personalities in industrial circles. Due to the fact that airborne electronic countermeasures systems and their operational counterparts-avionics equipment-have both already become an organic part of modern weapons systems, it follows that, in order to analyze the efficiency of airborne electronic countermeasures systems, it is also necessary to start with an estimate of the influence which they have on the efficiency of the weapons system as a whole. That is to say that it is necessary to research the relationship between the efficiency of the weapons system as a whole (that is, the operational aircraft) and airborne electronic countermeasures systems.

Normally, the penetration probability, survival probability, and aircraft utilization factors, as well as other similar factors, are all overall indices measuring and evaluating combat effectiveness. Therefore, they are also very well able to reflect the efficiency of electronic countermeasures in a combat environment. Due to the fact that these indices are all random quantities, it is necessary to use modern systems engineering methods in order to carry out analysis and calculations.

## II. Calculation of Penetration Probability and Survival Probability

First of all, we come to the calculation of penetration probabilities and survival probabilities for attack aircraft when these aircraft, loaded with electronic countermeasures systems, are penetrating enemy surface air defense systems.

Let us suppose that enemy air defense systems are composed of many independent weapons systems. Each weapons system, after acquiring the attacking aircraft, then goes through its firing, and, only after it is finished with its firing, can it then acquire the next target. At any one instant, any one weapons system is only able to carry out its firing against one target. When all weapons systems are in the process of firing, if another attacking aircraft enters the picture, it is only after the guns have stopped for a certain period of time, during which the weapons systems have no way to turn their fire on the new target, that they can finally engage it, and, this attacking aircraft will get through because there is no way for it to receive fire from the air defense systems. This is called penetration. This is actually a finite delay, multiple route, first come first served queuing system.

(1) Customer flow-attack aircraft grouping

We take the grouping of attacking aircraft as they enter the air defense system in time order and look at it as an event flow. Moreover, we recognize that it is the simplest Poisson flow. Therefore, during time  $t$ , we arrive at the probability of  $K$  aircraft as being:

$$P_K(t) = \frac{(\lambda t)^K}{K!} e^{-\lambda t}$$

$\lambda$  is the average number of events in unit time period, that is, the strength of the event flow. As far as the simplest flow is concerned,  $\lambda$  is a constant.

(2) Service counter-air defense system

If the service time is distributed according to a negative exponent, its pattern of distribution is:

$$F(t) = \mu e^{-\mu t}$$



$\mu = 1/\bar{T}_0$  is the average rate of service.

$\bar{T}_0$  is the average service time, that is, the average firing time of the air defense systems.

(3) Waiting time-stopover time

If we assume that the waiting time is also distributed according to a negative exponent, then, its distribution rate is

$$H(t) = \nu e^{-\nu t}$$

$$\nu = 1/\bar{T}_1$$

$\bar{T}_1$  is the average waiting time, that is, the average stopover time:

$$\bar{T}_1 = R_{\text{max}}/V$$

$R_{\text{max}}$  is the discovery distance for the radar under conditions of interference.

$V$  is the average speed of the attacking aircraft.

This is a classical  $M/M/N$  queuing system.

Let us assume that  $N(t)$  is the situation in the system at instant  $t$

$N(t) = K$  ( $K \leq n$ ), represents the instant  $t$  when there are  $K$  service counters in service. However, there are still  $n - K$  service counters idle.

$$N(t) = n + S \quad (S = 1, 2, 3, \dots)$$

This represents the instant  $t$  when, besides all the  $n$  service counters there are, there are still  $S$  customers (aircraft) entering the service system (air defense system) and being placed in a delay (stopover) status.

Let us assume

$$P(N(t) = K) = P_n(t)$$

$$P(N(t) = n + S) = P_{n+S}(t)$$

When the system tends toward a stable state, it is possible, through a set of simultaneous equations, to solve and obtain

$$P_0 = \frac{1}{\sum_{k=0}^{\infty} \frac{\alpha^k}{K!} + \frac{\alpha^0}{n!} \sum_{s=1}^{\infty} \frac{\lambda^s}{\prod_{m=1}^s (n+m\beta)}}$$

$$P_k = \frac{\alpha^k}{K!} \times P_0$$

$$P_{ns} = \frac{\alpha^s}{s!} \times \frac{\lambda^s}{\prod_{m=1}^s (n+m\beta)} \times P_0$$

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In this

$$\alpha = \frac{\lambda}{\mu}, \quad \beta = \frac{\nu}{\mu}$$

It is obvious that, at any instant at which the system is in a state of equilibrium, within the sphere of control of the air defense system, the value for the mathematical expectation that there is no aircraft passing through fire is

$$\bar{m}_0 = \sum_{s=1}^{\infty} s \times P_{ns}$$

Due to the fact that attacking aircraft which enter into the sphere of control of the air defense system have both a possibility of being shot and a possibility of not being shot and penetrating after getting past the stopover period, it is therefore possible to define the penetration probability as the ratio of the average number of aircraft leaving the air defense system in a given time and the number of aircraft entering the air defense system in a unit of time. That is,

$$P_T = \frac{\bar{m}_v}{\lambda T_s} = \frac{\bar{m}_v}{\lambda} = \frac{\bar{m}_v \beta}{\alpha}$$

$$P_T = \frac{\beta}{\alpha} \times \frac{\frac{\alpha^n}{n!} \sum_{s=1}^{\infty} \frac{s \alpha^s}{\prod_{m=1}^s (n + m\beta)}}{\sum_{K=0}^n \frac{\alpha^K}{K!} + \frac{\alpha^n}{n!} \sum_{s=1}^{\infty} \frac{\alpha^s}{\prod_{m=1}^s (n + m\beta)}}$$

From the formula, one can see that the penetration probability  $P_T$  is related to the three parameters  $\alpha$ ,  $\beta$  and  $n$ . It is possible to find this out from the forms concerned [2].

## 2. The process of raising the probability of penetration

According to definition,  $n$ ,  $\alpha$  and  $\beta$  are the three parameters which are related to the tactics and technology parameters for the attacking aircraft and the air defense system. They are also related to the parameters for the airborne electronics countermeasures system.

(1) The influence of the path number  $n$ . Because of the effect of the airborne countermeasures systems, the operation of air defense systems is disrupted, that is, the effective path number  $n$  is reduced. This, therefore, causes the penetration probability to increase.

a. Increasing the effective radiated power of airborne jammers  $G, P_r / \Delta F$  causes part of the radar in enemy air defense systems to be saturated or blocked and lose its effect. It becomes unable to carry out target assignment and long range guidance. This, therefore, causes the weapon path number  $n$  to be reduced

b. The utilization of various types of active and inactive means for cheating interference causes enemy air defense systems to carry out assignment and long distance guidance on false targets. This then occupies path numbers, and this causes the number of weapons path numbers used to shoot at attacking aircraft to be reduced, that is,  $n$  goes down.

(2) The influence of the parameter  $\alpha$ . From formula (1) and the forms in reference [2], it is possible to see that the larger  $\alpha$  becomes, the higher the penetration probability goes. Electronic countermeasures systems are capable of causing  $\alpha$  to increase in the two respects set out below:

a. Increasing the density  $\lambda$  of the attack flow, that is, make use of various types of deception measures in order to create false targets, or make use of pressure type noise interference to raise the rate of false warnings, causing pathways to be occupied by false signals, therefore, causing  $\lambda$  to increase.

b. Increasing the average firing time  $\bar{T}$  of air defense systems. Due to the effects of the use of electronic interference, the discovery probability of air defense radars is caused to drop. The probability of false warnings is increased, and this, therefore, causes the target acquisition time to increase. The time for radar acquisition of targets occupies an important position in the average firing time of air defense systems. 455

(3) The effect of the parameter  $\beta$ . From formula (1) and the forms in reference [2] it is possible to see that the larger  $\beta$  becomes, the higher is the probability of penetration. Electronic countermeasures systems are capable of causing an increase in  $\beta$  in the two respects set out below.

a. Reducing the average stopover or stationary time on a target  $\bar{T}$  increases interference power, and this will cause the minimum interference distance, that is, the self defense distance of the radar to decrease. This, therefore, shortens  $\bar{T}$  causing  $\beta$  to increase.

b. Increase the average firing time  $\bar{T}$ . This has already been discussed previously.

### 3. Survival probability $p$ .

After deriving the penetration probability, it is then possible to calculate the survival probability for the airframe with the self defense electronic countermeasures system.

$$P_s = 1 - (1 - P_r) \times P_k \quad (2)$$

$P_k$  is the weapons system (air to air, ground to air missile, cannon fire, anti-aircraft fire, and so on) kill probability against aircraft. Speaking in general terms, the effects of electronic countermeasures systems will also cause  $P_k$  to go down. This, therefore, increases the survival probability of the airframe to a higher level.

The tables set out below explain the penetration probabilities (Table 1) and the survival probabilities (Table 2) for attacking aircraft with particular combat situations and weapons.

表1 突防概率表

	$\lambda$ 架/分钟	$V$ (m/s)	$n$	$T_1$ (min)	$R$ (km)	$T_2$ (min)	$\alpha$	$\beta$	$P_T$
3. 不带电子对抗	2	350	4	2	60	2.86	4	9.7	0.175
4. 带电子对抗	3	350	1	3	10	0.48	9	5.25	0.483

Table 1 1. Penetration Probability Table 2. Aircraft 3. Not carrying electronic countermeasures 4. Carrying electronic countermeasures

表2 生存概率表

	$P_k$	$P_s$
2. 不带电子对抗	0.875	0.278
3. 带电子对抗	0.875	0.842

Table 2 1. Survival Probability Table 2. Not carrying electronic countermeasures 3. Carrying electronic countermeasures

It is possible for one to see that, due to the effects of airborne self defense electronic countermeasures systems, there is an increase of several fold in the survival probability of aircraft.

### III. Operational Gaming Analysis

Due to the fact that electronic countermeasures are activities directed in both the areas of radar and interference jamming, in the field of interference, when jamming is being carried out, it is necessary to give full consideration to the possibility that the enemy could adopt electronic countermeasures. Moreover, on the radar side, when jamming is being received, he is certainly also capable of adopting various types of anti-jamming measures. In this way, the two aspects of jamming and radar form the two sides of an operational game. By going through solutions for the game, it is possible to analyze the effectiveness of electronic countermeasures systems even better.

#### 1. Screening type electronic countermeasures gaming problems

In order to protect attacking aircraft breaking through on the enemy from air defense systems composed of the three elements of target assignment, long range guidance, and onboard guidance, it is generally possible to select for use the two types of techniques called indiscriminant jamming and long distance support jamming. In this type of situation, what it is first of all necessary to jam is the enemy's target assignment system. This causes it not to be able to accurately handle the aerial situation, to be unable to accurately carry through target assignment directives, and to be unable to accurately guide weapons. This raises the survivability of attacking aircraft.

Let us assume that  $K_1, K_2, K_3, \dots, K_n$  is the various types of combat order of attacking aircraft in the area of the attack.  $C_1, C_2, C_3, \dots, C_n$  is the plan for the assignment of various types of targets in the air defense area. 456

As far as the results when the two sides are gamed against each other are concerned, the unit for quantifying operational effectiveness is the average number of times attacking aircraft come under attack. Speaking from the point of view of the attackers, it is, under the conditions of a given number of aircraft and types of electronic jamming materiel, the precise directives relating to combat order which cause the average number of attacks received by attacking aircraft to be minimized.

Consider the actual combat situation given below. Protected by the use of jamming, the active jamming laid down by aircraft forms a  $J_1$  aerial jamming area. Inside this area, the radars used by enemy air defense systems are all unable to discover the aircraft. The passive jamming put out by jamming aircraft forms a jamming corridor  $J_2$ . In the same way, in this corridor, enemy radar is also unable to discover aircraft. Let us assume that the attacking side has one electronic jamming aircraft and two attack aircraft and that the defending side has two interceptor aircraft. Speaking in terms of the attacking side, it is simply a matter of finding out how to assign the number of attacking aircraft in the jamming cover areas  $J_1$  and  $J_2$  so as to cause the number of interceptions to be a minimum. This is a two person zero sum gaming problem. Reference [5] has already given us the solution to it.

## 2. Self defense type electronic countermeasures gaming problems

In aerial operations, in order to increase the survivability of operational aircraft, besides the requirement for specialized use of electronic jamming aircraft giving indiscriminate or long distance cover, normally, there is still a need for operational aircraft to be loaded with a set of self defense electronic countermeasures systems. These systems generally include radar warning equipment, positive jamming (to include deception as well as noise interference and other such forms) and passive jamming equipment. In this way, self defense electronic countermeasures systems possess numerous types of jamming capabilities.

In the same way, among enemy air defense systems, ground and airborne fire control radars of weapons also include many types of radar systems. The radars in these systems are also capable of selecting for use many types of counter jamming measures.

In the process of operations, the self defense electronic countermeasures systems on operational aircraft will make use of various types of jamming techniques. The jamming effects of these techniques on the radars of various types of systems as well as on the various types of counter jamming measures of the radars are all different. This has a direct influence on the survival probability of operational aircraft.

Let us assume that  $K_1, K_2, \dots, K_i$  respectively represent the various types of counter jamming techniques in airborne self defense countermeasures systems.

Let us assume that  $C_1, C_2, \dots, C_i$  respectively represent the radars and counter jamming measures of the various types of systems used in enemy air defense systems.

We take the survival probability of the operational aircraft to be the result of gaming. On the basis of actual combat statistics and probability calculations, it is possible to obtain airframe survival capabilities for radars and counter jamming measures during countermeasures with various types of different systems and jamming techniques.

This is a classical two person zero sum game. Its matrix is

	$C_1$	$C_2$	.....	$C_i$
$K_1$	$P_{11}$	$P_{12}$	.....	$P_{1i}$
$K_2$	$P_{21}$	$P_{22}$	.....	$P_{2i}$
$\vdots$	$\vdots$	$\vdots$		$\vdots$
$K_i$	$P_{i1}$	$P_{i2}$	.....	$P_{ii}$

Generally speaking, this type of game has no pure strategy. There are only mixed strategies. It is extremely difficult to use methods for solving equation sets; therefore, it is generally necessary to use iterative substitution methods or other approximation methods in order to solve it.

Let us assume that an airborne electronic countermeasures system has deception jamming, aimed static jamming, barrage static jamming, and jamming chaff projectiles as examples of four types of jamming techniques. We respectively use  $K_1, K_2, K_3$  and  $K_4$  to represent these. Moreover, among enemy air defense systems, there are airborne and ground fire control radars which have four types of systems such as conical sweep radar, linear sweep radar, quick change radar, and single pulse radar. We respectively use  $C_1, C_2, C_3$  and  $C_4$  to represent these.



During the process of operations, operational aircraft will make use of various types of jamming techniques. Due to the fact that various types of jamming techniques have different jamming effects on different systems of radar, it follows that survival probabilities for airframes would not be the same.

For example, the jamming effects of angular deception jamming on cone scanning radar are relatively good. However, its jamming effects on single pulse radar are relatively poor.

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In the same way, aimed type noise jamming is capable of effectively jamming point frequency radar. However, against fast changing frequency radar, it has relative difficulty in jamming, and so on.

On the basis of actual combat statistics and probability calculations, we are able to obtain the game matrix below.

	$C_1$	$C_2$	$C_3$	$C_4$
$K_1$	0.95	0.97	0.82	0.11
$K_2$	0.65	0.73	0.16	0.89
$K_3$	0.52	0.22	0.63	0.53
$K_4$	0.80	0.19	0.40	0.71

Making use of iterative substitution methods, when the number of iterative substitutions is  $N=500$ , the mixed solution for the game matrix described above has mixed strategies for the jamming side as shown below.

$K_1$	$K_2$	$K_3$	$K_4$
0.258	0.286	0.454	0.002

The mixed strategies for the radar side are

$C_1$	$C_2$	$C_3$	$C_4$
0	0.152	0.456	0.392

The game value is  $V=0.5456$  .

This is to say that, on the basis of the survival probability matrix described above, if the attacking side has, respectively, a 25.8%, 28.6%, and a 45.4% probability of laying down deceptive jamming, aimed type noise jamming, and barrage type noise jamming, then, this will cause the survival probability for the airframes to be a maximum, reaching 54.6%.

#### IV. Analysis of Actual Combat Results

Normally, airborne electronic countermeasures have functions which appear in the discovery of the threat to tracked aircraft, recognition and warning, as well as specifying the priority of the threat. Moreover, in an environment of numerous signals, they carry out jamming against these threats. Therefore, they destroy or greatly reduce the operation of weapons systems and their effectiveness.

Within the shortest time, the capability of arriving at the results described above is a quantitative measure for each particular electronic countermeasures system. The effects of electronic countermeasures systems will extend the operational lives of aircraft and flight personnel, that is, they will raise the number of operational missions which an aircraft completes within a specified period of time.

##### 1. Assumptions in Operational Models

We assume the actual combat situation below:

- .there are 100 aircraft prepared to enter the combat (carry out attack missions).
- .each aircraft is capable of being used in two sorties per day.
- .the rear services resupply system is capable, within an average of three days, of taking damaged aircraft, repairing and returning them, and refitting them for combat.
- .during attack missions, half the aircraft hit are lost or cannot be repaired.
- .the total time of the combat is 15 days
- .during the duration of the combat, there is no resupply of new aircraft

Let us assume that at the beginning of each day of combat, the number of operational aircraft which it is possible to use is  $N_i$ . Then,

$$N_i = \left(1 - \frac{P}{E}\right) \times \left[N_{i-1} + \frac{r \times P}{E} N_{i-1-r}\right]$$

In this equation  $p$  - when there is no electronic countermeasures protection system is the average rate of hits by air defense systems on each aircraft

$E$  - electronic countermeasures protection factor

$r$  - rate of aircraft survival and return

$r-1$  - the number of aircraft lost /  $P$  x the number of sorties sent out

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On the basis of the assumptions above,  $r=0.5$ .

$T$  - average repair time (day numbers represented using the sequence numbers of the days of combat)

$i$  - sequence number of combat day

It is obvious that  $N_0=100$

In the equation above,  $P$  and  $E$  are two of the most important parameters.  $E$  is the capability of electronic countermeasures systems to lower weapons efficiency and reduce their hit probability.  $p$  is the complement of the survival probability for an aircraft in one sortie. These are decided on the basis of two factors. The first is the survival capability of the aircraft itself (speed, maneuverability, low altitude performance, and so on). The second is the situation regarding the number, effectiveness, and readiness of anti-aircraft systems.

Giving consideration to various types of actual combat factors, we assume that, in a single attack, the probabilities  $P_i$  of an aircraft being hit are, respectively

$$P_1=0.1, P_2=0.05, P_3=0.025$$

$P_1$  is aircraft of ordinary capabilities.  $P_2$  is, then, for aircraft of relatively good performance. And,  $P_3$  alone is for aircraft with excellent low altitude, high speed performance.

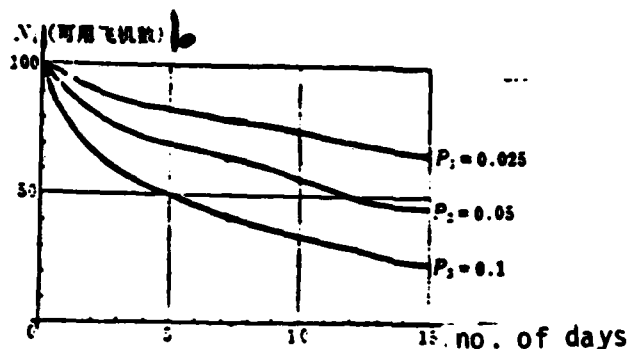


Fig. 1 Simulated Operational Model Aircraft Useability Curves 1.  
Number of Useable Aircraft

In this way, we can figure out, for different  $P$ , the number of operational aircraft which can be used on each day. This is shown in Fig. 1. This Fig. clearly shows the effect of the value of  $P$ .

## 2. Initial Results

In order to analyze the effects of electronic countermeasures systems, we define  $U$  to be the aircraft utilization factor.  $U =$  the number of aircraft sorties/the number of aircraft losses. Moreover, we define the electronic countermeasures improvement factor as  $IF = U_1/U_0$ .  $U_1$  and  $U_0$  respectively represent the aircraft utilization factor with and without electronic countermeasures cover.

The electronic countermeasures protection factor  $E$  represents the capability of electronic countermeasures techniques to lower weapons hit probabilities. It is determined by the capabilities of the weapons and the electronic countermeasures, battlefield reaction capabilities, and intelligence capabilities. On the basis of a theoretical analysis of noise jamming, it has an  $E$  value of approximately 10 against gun aiming radar and an  $E$  value of from 5 to 10 against ground to air missile systems. During the Vietnam war,

the average value of  $E$  was 8. In current calculations,  $E$  is taken as 2.

The front half of Table 3 is a set of the most important operational factors derived from Table 1. These show, for 15 days of combat, the total number of aircraft sent out for each  $P$  value, the number of aircraft lost, and the utilization factor for the aircraft. The last half then shows the situation when there are electronic countermeasures.

The first column in Fig. 3 is - for 15 days of combat - the total number of attack operations completed. The use of electronic countermeasures caused the effective number of sorties to respectively increase 12%, 23%, and 40%.

The second column shows the total number of aircraft lost during the period of combat. It is possible to see that the use of electronic countermeasures very greatly reduces aircraft losses.

P	不带电子对抗 1			2 带电子对抗			电子对抗改善因子 IF 9
	3 总架次	4 损失飞机数	5 飞机利用率 $U_1$	6 总架次	7 损失飞机数	8 飞机利用率 $U_2$	
0.1	1365	68	30	1923	52	37	1.65
0.05	1923	52	37	2361	30	79	2.13
0.025	2361	30	79	2653	17	156	1.98

Table 3. Electronic Countermeasures Improvement Factor 1. Without Electronic Countermeasures 2. Carried Electronic Countermeasures 3. Total Aircraft Trips 4. Number of Aircraft Lost 5. Aircraft Utilization Factor 6. Total Aircraft Trips 7. Number Aircraft Lost 8. Aircraft Utilization Factor 9. Electronic Countermeasures Improvement Factor

The third column is the aircraft utilization factor  $U$ . It gives overall consideration to both of the two factors above. The final column is the electronic countermeasures improvement factor  $IF$ . Its numerical value is between 1.85 and 2.13. This shows that, after one makes use of electronic countermeasures, the operational life of aircraft and aircrews, as shown by the previous number of sorties that were destroyed, increased at least 85%.

### 3. Actual Combat Situation Analysis

On the basis of a local conflict in the latter part of the '70s of this century, the statistical data on actual aircraft useability rates and loss rates for the air forces of sides A, B, and C, make it possible to obtain these important data.

The survival return rate for aircraft in the air force of side A was  $r=82\%$  .

The aircraft utilization factor was  $U=102$  .

Moreover, the aircraft survival return rate for the air force of side B was  $r=33\%$  . In the same way, it is possible to solve for  $U=24$  .

For the air force of the C side  $r=38\%$   $U=28$  .

It is possible to see from this that the utilization factor for the aircraft in the A side air force is much, much higher than those for the B and C side air forces. Besides such factors as aircraft capabilities and innate quality of aircrews, effective electronics countermeasures are also an important factor.

Fig. 2 is based on data analysis and contains curves done after a normalizing unitary treatment. It is possible to see that the form and characteristics of the curve for actually usable aircraft are extremely similar to the curves which our analysis produced in Fig. 1.

### V. Conclusion

Above, we have gone through several types of methods to analyze the operational effectiveness of airborne electronic countermeasures, and we obtained several preliminary results. At the present time, another method for solving this problem is to make use of the operational effectiveness obtained for airborne electronic countermeasures by putting together large scale hardware and complicated software to control an electronic countermeasures environment simulation system in order to carry out simulations of actual combat. It appears that these two types of methods will both develop unabated and mutually complement each other. The result will be a relatively well rounded solution to this problem.

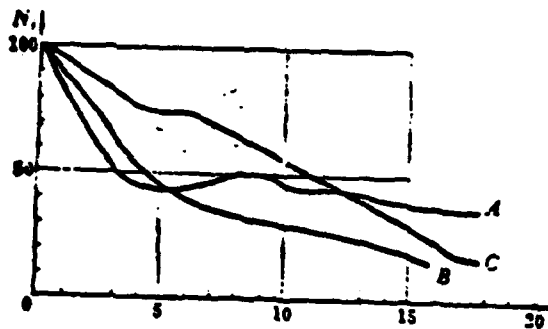


Fig. 2 Aircraft Useability Curves for a Certain Number of Combat Situations

This article has been reviewed by Comrade Yu (Surname unclear) Nengjing, who has given us his valuable opinions. The author wishes to express his heartfelt gratitude.

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## EFFICIENCY ANALYSIS OF AIRBORNE ELECTRONIC COUNTERMEASURES (ECM) SYSTEMS

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### Abstract

With the developing of ECM technology, airborne ECM systems have been a very important part of avionics in fight aircraft. Its efficiency evaluation has become a problem to which is paid much more attention by people.

First of all, this paper describes the function and position of ECM systems in modern air warfare and analyzes the importance of efficiency evaluation, then the method of operations research is used to analyze and calculate. The queuing system to be composed of attack aircrafts and air defence system is considered as a typical M/M/N queuing system. The penetration probability and survival probability is calculated by used of the queuing theory. There are two types of airborne ECM system, one is screen system, another is self protection system. The effect of ECM applications on the system efficiency is analyzed by means of game theory in those two cases. Finally, a method of calculation of the aircraft utilization factor is given by analyzing a combat process of EW.

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