Research on Evaluating Method of Army Air Defense Force’s Fighting Capacity Based on Index System

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Abstract. This paper analyzed the systemic fighting capacity of the army air defense force. Through this analysis we can master the army air defense force’s framework and the basic factors that affect its fighting capacity then to judge whether the capacity is fit for its task. On the base of the analysis of the army air defense force’s framework, the paper set up mathematical models about army air defense force system and its branch systems. Through contract between the calculating outcome and the operation imitate data the paper can evaluate the system and the branch system’s capacity.

1. Introduction
The Army Air Defense Force can be divided into three parts according to its combat capability, namely: the early warning reconnaissance capability generated by the early warning reconnaissance system, the command and control capability generated by the command and control system, and the firepower strike capability generated by the weapon system[1-3].

2. Early Warning And Reconnaissance Capabilities Structure

2.1. What The Feature Contains
According to the principle of early warning reconnaissance capability generation, it can be divided into: effective early warning reconnaissance distance, early warning reconnaissance scope, effective early warning reconnaissance time, MTTR (mean fault repair time), MTBF (mean time between failures), failure rate, anti-interference ability. Its structure is shown in Figure 1:

Figure 1. Structure of the early warning reconnaissance capability.
2.2. Early Warning Reconnaissance Capability Value Setting

Assume that the capability value of the effective early warning reconnaissance distance is X1, the capability value of the early warning reconnaissance range is X2, the capability value of the effective early warning reconnaissance time is X3, and the MTTR (mean time to repair time) is X4, MTBF (mean time between failures) The ability value is X5, the failure rate is X6, the anti-interference ability is X7, and FX is the early warning reconnaissance ability. Because the elements interact and relate to each other, FX uses the index method, then:

\[ F(X) = K_x X_1^{α_1} X_2^{α_2} X_3^{α_3} X_4^{α_4} X_5^{α_5} X_6^{α_6} X_7^{α_7} \] (1)

Where: F(X) is the value of the early warning reconnaissance ability; KX is the adjustment coefficient; \( α_1, α_2, α_3, α_4, α_5, α_6, α_7 \) is the power exponent of the corresponding ability. Through the calculation of the value of the early warning reconnaissance capability, the reliability of the early warning reconnaissance system to complete the task can be evaluated. If \( (\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6) \in F(X) \) and \( \theta_1 < \theta_2 < \theta_3 < \theta_4 < \theta_5 < \theta_6 \) are assumed, the capabilities of the early warning reconnaissance system and the reliability of the completed task are shown in Table 1:

**Table 1.** Reliability of the early warning reconnaissance system and the reliability of the completed task

| Early warning reconnaissance capability value | range | Ability level | Complete the scope of the task |
|---------------------------------------------|------|---------------|------------------------------|
| F(X)                                        | [θ₁, θ₂) | excellent     | Can complete various tasks  |
| F(X)                                        | [θ₂, θ₃) | good          | Can complete most tasks     |
| F(X)                                        | [θ₃, θ₄) | Medium        | Can complete basic tasks    |
| F(X)                                        | [θ₄, θ₅) | weak          | Can complete simple tasks   |
| F(X)                                        | [θ₅, θ₆) | difference    | Basically unable to complete the task |

In the table: The value of \( θ_i \) (1 ≤ i ≤ 6, i ∈ N) is determined by the experience value of the actual exercise; the capability level is divided according to the ability to complete the task; the scope of the completed task is divided according to the overall situation of the completed task.

3. Command And Control Capability Structure

3.1. Feature Contains Content

According to the principle of component generation of command and control capabilities, it can be divided into: air-condition fusion capability, MTBF, target recognition capability, communication transmission capability, decision time, instruction transmission and execution time. Its structure is shown in Figure 2:

![Figure 2. Figure of the structure of command and control capabilities](image-url)
3.2. Command And Control Capability Value Setting\[4][7]

Assume that the capability value of the air-condition fusion is \( Y_1 \), the capability value of the MTBF is \( Y_2 \), the capability value of the target identification is \( Y_3 \), the capability value of the communication transmission is \( Y_4 \), the capability value of the decision time is \( Y_5 \), and the capability value of the command transmission and execution time is \( Y_6 \). \( F_Y \) is the value of command and control ability. Because of the mutual influence and correlation between various elements, \( F_Y \) adopts the index method, then:

\[
F(Y) = K_Y Y_1^{\beta_1} Y_2^{\beta_2} Y_3^{\beta_3} Y_4^{\beta_4} Y_5^{\beta_5} Y_6^{\beta_6}
\]  

(2)

Where: \( F(Y) \) is the command control ability value; \( K_Y \) is the adjustment coefficient; \( \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6 \) is the power index of the corresponding ability. Through the calculation of the command and control capability value, the reliability of the command and control system to complete the task can be evaluated. If \( (\rho_1, \rho_2, \rho_3, \rho_4, \rho_5, \rho_6) \in F(Y) \) and \( \rho_1 < \rho_2 < \rho_3 < \rho_4 < \rho_5 < \rho_6 \) are used, the capability of the command and control system and the reliability of the completed task are as shown in Table 2:

| Command and control ability value | range | Ability level | Complete the scope of the task |
|-----------------------------------|-------|---------------|-------------------------------|
| F(Y) \[ \rho_1, \rho_2 \]        | weak  | Can complete simple tasks |
| F(Y) \[ \rho_2, \rho_3 \]        | Medium| Can complete basic tasks |
| F(Y) \[ \rho_3, \rho_4 \]        | good  | Can complete most tasks  |
| F(Y) \[ \rho_4, \rho_5 \]        | excellent | Can complete various tasks |

In the table: The value of \( \rho_j (1 \leq j \leq 6; j \in N) \) is determined by the performance of the superior evaluation and equipment; the capability level is divided according to the ability to complete the task; the scope of the completed task is divided according to the overall situation of the completed task.

4. Fire strike capability structure

4.1. Feature Contains Content

The Army Air Defense Air Defense Firepower Network is mainly composed of three parts: the artillery, the portable missile, and the air defense missile. Because of the different performance characteristics of each part of the weapon, the elements of the firepower capability are also different. They are:

(1) The elements included in the artillery: failure rate, firing rate, effective range, firing accuracy, power, fire density, aiming ability, solution accuracy, equipment response time, strike area, multi-target combat capability, battlefield survivability;

(2) The elements of the portable missile include: failure rate, power, aiming ability, tracking and guidance capability, battlefield survivability, personnel response time, strike zone, anti-interference ability;

(3) The elements of air defense missiles include failure rate, aiming ability, solution accuracy, tracking and guidance capability, battlefield survivability, equipment and personnel response time, strike zone, anti-interference ability, and multi-target combat capability.

The structure of the firepower capability is shown in Figure 3:
4.2. Firepower Ability Value Setting

Assume that the ability value of the rate of fire is $Z_1^{100}$, the ability value of the failure rate is $Z_2^{100}$, the ability value of the effective range is $Z_3^{100}$, the ability value of the shooting accuracy is $Z_4^{100}$, the power value of the power is $Z_5^{100}$, the power value of the fire density is $Z_6^{100}$, and the aiming ability

The ability value is $Z_7^{100}$, the ability value of the solution precision is $Z_8^{100}$, the ability value of the tracking guidance capability is $Z_9^{001}$, the capability value of the battlefield survivability is $Z_{10}^{100}$, the capability value of the equipment/person response time is $Z_{11}^{100}$, and the capability value of the strike zone is $Z_{12}^{100}$. The ability value of the anti-interference ability is $Z_{13}^{010}$, and the capability value of the multi-target anti-attack capability is $Z_{14}^{100}$. Among them: $Z_n^{100}$ is the ability value of the high-altitude strike capability; $Z_n^{010}$ is the ability value of the strike capability; $Z_n^{001}$ is the capability value of the anti-aircraft firepower capability, $1 \leq n \leq 14$; $n \in N$. Assume $F_{Z1}$ is the value of the anti-aircraft firepower capability. Because of the interaction and correlation between the various elements, $F_{Z1}$ uses the index method, then:

$$F(Z1) = K_{Z1}(Z_{10}^{100})^{\gamma_1}(Z_{11}^{100})^{\gamma_2}(Z_{12}^{100})^{\gamma_3}(Z_{13}^{010})^{\gamma_4}(Z_{14}^{001})^{\gamma_5}(Z_{15}^{001})^{\gamma_6}(Z_{16}^{001})^{\gamma_7}(Z_{17}^{001})^{\gamma_8}(Z_{18}^{001})^{\gamma_9}(Z_{19}^{001})^{\gamma_{10}}(Z_{20}^{001})^{\gamma_{11}}(Z_{21}^{001})^{\gamma_{12}}(Z_{22}^{001})^{\gamma_{13}}(Z_{23}^{001})^{\gamma_{14}}$$

(3)

Where: $F(Z1)$ is the value of the high-alloy firepower; $K_{Z1}$ is the adjustment factor; $\gamma_n$ ($1 \leq n \leq 12$; $n \in N$) is the power exponent of the corresponding element's ability. Let $F_{Z2}$ is the value of the portable missile's firepower capability. Because of the interaction and correlation between the various elements, $F_{Z2}$ uses the index method, then:

$$F(Z2) = K_{Z2}(Z_{21}^{100})^{\gamma_1}(Z_{22}^{100})^{\gamma_2}(Z_{23}^{010})^{\gamma_3}(Z_{24}^{001})^{\gamma_4}(Z_{25}^{001})^{\gamma_5}(Z_{26}^{001})^{\gamma_6}(Z_{27}^{001})^{\gamma_7}(Z_{28}^{001})^{\gamma_8}(Z_{29}^{001})^{\gamma_9}(Z_{30}^{001})^{\gamma_{10}}(Z_{31}^{001})^{\gamma_{11}}(Z_{32}^{001})^{\gamma_{12}}(Z_{33}^{001})^{\gamma_{13}}(Z_{34}^{001})^{\gamma_{14}}$$

(4)

Where: $F(Z2)$ is the firepower strike capability value of the portable missile; $K_{Z2}$ is the adjustment coefficient; $\gamma_n$ ($1 \leq n \leq 8$; $n \in N$) is the power exponent of the corresponding element capability. Let $F_{Z3}$ is the firepower strike capability value of air defense missiles. Because of the mutual influence and correlation between various elements, $F(Z3)$ adopts the index method, then:

$$F(Z3) = K_{Z3}(Z_{31}^{001})^{\gamma_1}(Z_{32}^{001})^{\gamma_2}(Z_{33}^{001})^{\gamma_3}(Z_{34}^{001})^{\gamma_4}(Z_{35}^{001})^{\gamma_5}(Z_{36}^{001})^{\gamma_6}(Z_{37}^{001})^{\gamma_7}(Z_{38}^{001})^{\gamma_8}(Z_{39}^{001})^{\gamma_9}(Z_{40}^{001})^{\gamma_{10}}(Z_{41}^{001})^{\gamma_{11}}(Z_{42}^{001})^{\gamma_{12}}(Z_{43}^{001})^{\gamma_{13}}(Z_{44}^{001})^{\gamma_{14}}$$

(5)
Where: \( F(Z3) \) is the fire strike capability value of the air defense missile; \( K_{Z3} \) is the adjustment coefficient; \( \gamma \) \((1 \leq n \leq 9; n \in N)\) is the power exponent of the corresponding element capability.

Let \( F_Z \) is the fire attack capability value of the Army Air Defense Weapon System. According to the structure of the system, \( F_Z \) uses the index method to sum, then:

\[
F(Z) = K_1 F_{Z1}^{\gamma_1} + K_2 F_{Z2}^{\gamma_2} + K_3 F_{Z3}^{\gamma_3}
\]

Where: \( F(Z) \) is the fire attack capability value of the Army Air Defense Weapon System; \( K_1, K_2, \text{and } K_3 \) are adjustment coefficients; \( \gamma \) \((n \in N)\) is the power index corresponding to the firepower of the sub-weapon system.

Through the calculation of the firepower capability value, the reliability of the Army Air Defense Weapon System for the completion of the mission can be assessed. If \( (\sigma_1, \sigma_2, \sigma_3, \sigma_4, \sigma_5, \sigma_6) \in F(Z) \), and \( \sigma_1 < \sigma_2 < \sigma_3 < \sigma_4 < \sigma_5 < \sigma_6 \), the capabilities of the Army Air Defense Weapons System and the reliability of the completed mission are shown in Table 3:

**Table 3.** Reliability reference for the capabilities and completion tasks of the Army Air Defense Weapons System

| Firepower ability value | range | Ability level | Complete the scope of the task |
|-------------------------|-------|--------------|-------------------------------|
| F(Z)                    | [\sigma_6, \sigma_5] | excellent   | Can complete various tasks   |
| F(Z)                    | [\sigma_5, \sigma_4] | good        | Can complete most tasks      |
| F(Z)                    | [\sigma_4, \sigma_3] | Medium      | Can complete basic tasks     |
| F(Z)                    | [\sigma_3, \sigma_2] | weak        | Can complete simple tasks    |
| F(Z)                    | [\sigma_2, \sigma_1] | difference  | Basically unable to complete the task |

In the table: The value of \( \sigma_k \) \((1 \leq k \leq 6; k \in N)\) is determined by the empirical value of the actual exercise and the weapon characteristics; the capability level is divided according to the ability to complete the task; the scope of the completed task is divided according to the overall situation of the completed task.

5. System Analysis

It can be known that the index of the system's capability index is more accurate using the exponential method. Therefore, assuming \( F_T \) is the system capability value, then:

\[
F(T) = K_T F_T^{\sigma_n} F_Z^{\eta_n}
\]

Where: \( F(T) \) is the capacity value of the Army air defense system; \( K_T \) is the adjustment parameter; \( \sigma_n \) \((1 \leq n \leq 3; n \in N)\) is the power exponent of the corresponding system.

Through the calculation of the system's ability value, the reliability of the Army's air defense system to complete the task can be assessed. Assuming \( (\eta_1, \eta_2, \eta_3, \eta_4, \eta_5, \eta_6) \in F(T) \) and \( \eta_1 < \eta_2 < \eta_3 < \eta_4 < \eta_5 < \eta_6 \), the capability of the Army's air defense weapon system and the reliability of the completed task are shown in Table 4:

**Table 4.** Reliability reference for the capabilities and completion tasks of the Army Air Defense Weapons System

| System capability value | range | Ability level | Complete the scope of the task |
|-------------------------|-------|--------------|-------------------------------|
| F(T)                    | [\eta_5, \eta_6] | excellent   | Can complete various tasks   |
| F(T)                    | [\eta_5, \eta_4] | good        | Can complete most tasks      |
| F(T)                    | [\eta_4, \eta_3] | Medium      | Can complete basic tasks     |
| F(T)                    | [\eta_3, \eta_2] | weak        | Can complete simple tasks    |
| F(Z)                    | [\eta_2, \eta_1] | difference  | Basically unable to complete the task |
In the table: the value of \( \eta_h \ (1 \leq h \leq 6, \ h \in N) \) is determined by the experience value of the actual exercise, the weapon characteristics, the superior evaluation, the expert opinion, etc.; the capability level is divided according to the ability to complete the task; the completion task range is divided according to the overall situation of the completed task.

6. Conclusion

Analysis of the operational capabilities of the Army's air defense system is the basis for improving the operational capabilities of the Army's air defense system. It is of great significance for improving the weapons and equipment of the Army's air defense system and improving its combat capability. This paper only discusses the elements, characteristics, structure, work flow and capability rating of the Army Air Defense System. It can not meet the modeling requirements of the theoretical research of the Army Air Defense System. It is necessary to compare the capability characteristics with the corresponding equipment. Combine and complete and standardize the data interaction modeling method to develop a complete set of methods and models for analyzing the operational capabilities of the Army air defense system.

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