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MEMORANDUM FOR: The Director of Central Intelligence

FROM : John N. McMahon
Deputy Director for Operations

SUBJECT : MILITARY THOUGHT (USSR): Principles of the Structure of the US Antimissile Defense Radar System

1. The enclosed Intelligence Information Special Report is part of a series now in preparation based on the SECRET USSR Ministry of Defense publication Collection of Articles of the Journal "Military Thought". This article describes the layout of the US Ballistic Missile Early Warning System (BMEWS), the types and capabilities of equipment at a BMEWS center, and some of the new developments to improve missile detection (Project Teepee, Project Madre, Midas satellites). By way of assessment, the authors find the cost of BMEWS out of proportion to its effectiveness. This article appeared in Issue No. 1 (71) for 1964. [redacted]

2. Because the source of this report is extremely sensitive, this document should be handled on a strict need-to-know basis within recipient agencies. For ease of reference, reports from this publication have been assigned [redacted]

[redacted]
John N. McMahon

[redacted]

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MILITARY THOUGHT (USSR): Principles of the Structure of the US Antimissile Defense Radar System

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Summary:

The following report is a translation from Russian of an article which appeared in Issue No. 1 (71) for 1964 of the SECRET USSR Ministry of Defense publication Collection of Articles of the Journal "Military Thought". The authors of this article are General-Leytenant of Engineer-Technical Service N. Moskovchenko and Engineer Lieutenant Colonel V. Belyanskiy. This article describes the layout of the US Ballistic Missile Early Warning System (BMEWS), the types and capabilities of equipment at a BMEWS center, and some of the new developments to improve missile detection (Project Teepee, Project Madre, Midas satellites). By way of assessment, the authors find the cost of BMEWS out of proportion to its effectiveness.

End of Summary

[redacted] Comment:

The SECRET version of Military Thought was published three times annually and was distributed down to the level of division commander. It reportedly ceased publication at the end of 1970. [redacted]

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Principles of the Structure of the US Antimissile Defense Radar System

by

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The problem of combating intercontinental ballistic missiles is one of the most difficult and complex problems ever encountered by the armed forces of any country. This is due to the three peculiarities of ballistic missiles: their high average velocity allows very short reaction time for the defense system, the small dimensions and configuration of the warheads of ballistic missiles make detection difficult, and their low vulnerability makes their destruction difficult.

The first two factors emphasize the particular importance for defense and, at the same time, the great difficulty of developing a system of long-range reconnaissance against ballistic missiles and the radar system, which is the main element of such a system.

What is the role and place of the radar system in the overall complex of antimissile defense equipment?

The antimissile defense radar system must accomplish the following tasks:

-- detection of the launches of ballistic missiles and artificial earth satellites, i.e. the determination of the launch site, direction, and velocity of flight of ballistic missiles and satellites during the initial phases of their trajectories; this task is accomplished by early-warning radars;

-- detection and determination of the trajectories of the warheads of ballistic missiles and of the trajectories of satellites that are attacking or flying by from any azimuthal direction; the long-range detection system is called on to accomplish this task.

Such a division of the tasks of radar reconnaissance is explained by the difference in the character of the radar equipment employed, which will be discussed in more detail below.

A radar system, being a component part of an antimissile defense system, must warn the command posts of the antimissile defense system of the launching of ballistic missiles for the purpose of declaring an alert, must determine the ballistic missile launching area for calculating the location of the launch sites and neutralizing them, must compute and issue data on the trajectories of the ballistic missiles to the command posts and antimissile defense firing complexes for destroying the missiles in flight, must determine the launchings of satellites and continuously conduct space reconnaissance for compiling charts and tables of the trajectories of all satellites for the purpose of determining their nationality and purpose (reconnaissance satellites, communications satellites, navigation satellites, etc.).

Thus, in the development of a radar system it must be taken into account that its field of observation is based primarily on the necessity of guaranteeing the maximum possible reaction time for accomplishing the tasks enumerated.

At the present time the USA is carrying out intensive construction of the BMEWS long-range detection system. The early-warning equipment is in the development stage. The work is being conducted in two directions: the development of ground-based radars capable of detecting targets beyond the horizon (Project "Teepee") and a satellite-based early-warning system (Project "Midas"). Because of the definite technical difficulties involved in the development of satisfactorily effective ground-based early-warning radars, the second direction is considered the most promising and is being given the most attention. However, the Midas system is still in the study stage.

<u>The long-range detection radar system.</u> The USA, exploiting its geographical possibilities, has moved its long-range detection equipment some 2,500 to 3,000 kilometers north of its own borders, which, according to their intention, should afford the possibility of detecting ballistic missiles attacking the territory of the United States from the north 15 to 20 minutes before they hit.

The long-range detection line consists of three radar centers. One center is in Greenland, near Thule; the second is in Alaska (Shelya Peninsula [sic], city of Clear); the third is in Northern England, in a remote spot in Yorkshire, close to Fylingdales.

The detection sectors of all the centers are oriented in the northern direction, and the total zone of the system is designed so as to ensure scanning of the axes of missile danger from all the possible launch sites in the territory of the USSR.

The detection zone of each radar center consists of two fan-shaped layers of beams that are wide in the azimuthal plane and narrow in the plane of elevation.

The first layer lies within the angles of elevation from two to five degrees, the second from six to ten degrees elevation. The sector width in azimuth angle at Thule is 150 degrees, and at Clear and Fylingdales about 110 degrees. The detection range is 4,500 to 5,000 kilometers.

The BMEWS system uses two basic types of radar. One of them, the AN/FPS-50 detection radar, can provide the detection of a great number of targets, and is intended for the detection of targets, rough measurement of their coordinates, tentative determination of the parameters of their trajectories and of the impact area of the ballistic missiles, and for the issuing of target designation among selected targets to the tracking radars.

The AN/FPS-50 is a coherent-pulse radar that operates in the decimeter range. The scan sector is 38 degrees in azimuth. For this reason, each center has several radars which ensure the necessary width of the detection zone of the center. In the elevation plane the radar forms two fixed partial radiation patterns three to four degrees wide. In the azimuthal plane the radiation pattern is about one degree wide. The antenna of the radar is fixed. The azimuth scanning in a given sector is done by oscillating the beam electrically.

The second main type of radar, the AN/FPS-49 tracking radar, can track only one target and is intended for a precise measurement of the target coordinates, for determining the parameters of the trajectory, for predicting the point of impact, and for issuing target designation to the reconnaissance radars of the Nike Zeus firing complexes. These radars can operate also in the detection mode and can scan and search for targets independently.

The AN FPS-49 radar is a monopulse radar that operates in the decimeter range and has a rotating antenna with a parabolic reflector. The scan sector is 360 degrees in azimuth and 90 degrees in elevation. The radar can operate in either the circular or sector scan mode. Its range is 4,800 kilometers. The radiation pattern is about two degrees in both azimuth and elevation.

The IBM-7090 computer is used at the BMEWS system centers for processing the radar information, computing the parameters of the trajectory and points of impact of the ballistic missiles and also the location of the launch sites, and for controlling the operation of the equipment automatically. The IBM-7090 has the following principal characteristics: 225K operations per second, memory capacity of 32K ten-digit numbers, memory access time of 2.4 microseconds, and data input-output rate of 300K characters per second.

The composition and arrangement of the main equipment at the Thule center is typical of the BMEWS system centers. It has four detection radars, three tracking radars and two IBM-7090 computers.

The arrangement of the main equipment of the center at the site is shown in the sketch below.

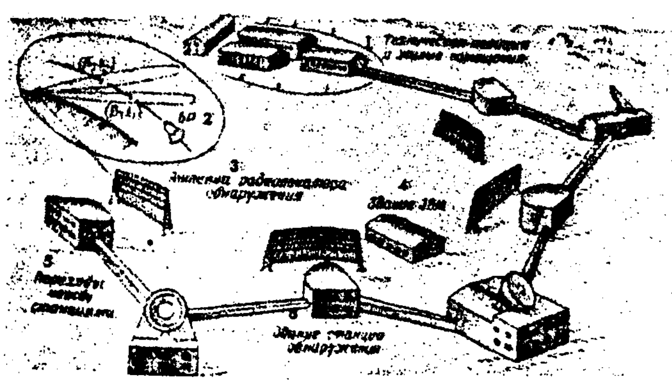

Diagram of BMEWS Center in Thule

Legend

1 Technical position and living quarters
2 Ballistic missile
3 Detection radar antenna
4 Computer building
5 Passages between stations
6 Detection station building

The center cost 500 million dollars, has a T/O of about 1,000 persons, and requires 35 to 40 thousand kilowatts of power; its operating expense is about 100 million dollars per year. The center was put into operation in October 1960, but the AN/FPS-49 radars are still not ready for operation.

The center at Clear has three AN/FPS-50 radars and two AN/FPS-49 radars. The center was put into operation in July 1961; however, like Thule, this center is operating without the AN/FPS-49 radars.

The center in Fylingdales is supposed to have only three AN/FPS-49 radars -- two to operate in the detection mode and one in the tracking mode.

The center was supposed to be put into operation at the end of 1962, but, according to the latest information, construction has not yet been completed.

The cost of constructing the BMEWS system is estimated at one billion dollars. The number of service personnel at the three centers is about 2,500 to 3,000 people. The entire system is expected to be put into operation in 1963-1964.

The information from each radar center must be transmitted to the center of the North American Continental Air Defense Command in Colorado Springs, Colorado. Here it is collated and processed by computer, supplemented and compared with information from other sources (for example, from satellite detection and tracking systems) and transmitted to electronic plotting boards. The assessment of the situation and final decision regarding the degree of threat and existence of an attack by ballistic missiles is made by the commander of air defense.

The situation presented on the display boards at the air defense center is also transmitted to electronic displays at the operations center of the Strategic Air Command in Omaha, Nebraska, and to the Department of Defense in Washington.

Information on satellites that are detected by the BMEWS system is sent to the control post of the satellite detection and tracking system, which is also in Colorado Springs.

Ramified networks of wire (cable) and radio communications are used for transmitting the information from each radar center to the air defense center. The independence and separation of the communications lines in space should provide reliability and viability of the entire communications system.

Both the existing and specially developed communications lines of different types are used in the organization of the communications. The newly developed lines include underground and underwater cables, radio-relay lines, and tropospheric communications equipment.

The following facts and figures give a picture of the grandiose dimensions and technical complexity of the BMEWS system.

The need for highly accurate measurement of the angular coordinâtes and for a long operating range calls for the use of very large antennas. The AN/FPS-50 antenna is 10 meters high and 126 meters wide; it is made of nickel steel and is supposed to withstand a wind velocity of up to 300 kilometers per hour, temperatures down to minus 54 degrees C, and coatings of ice up to 15 centimeters thick, which can weigh up to 1,500 tons and thus double the weight of the antenna.

The radiated pulse power of the radar is 10 megawatts, and the mean power 600 kilowatts. The radar has eight operating klystron transmitters and the same number in reserve. The klystron is three meters long and weighs half a ton; it operates on 120 kilovolts. Each transmitter weighs 278 tons.

The AN/FPS-49 tracking radar has a 25.6-meter parabolic reflector. The antenna is housed in a spherical radio-transparent cover 42 meters in diameter. The rotating part of the antenna weighs 30 tons. The radar uses a transmitter with a klystron that is up to 10 meters high and has pulse power on the order of 10 megawatts.

The number of parts in the complete installation can be judged from the following.

The BMEWS system apparatus is said to contain: 780 thousand transistors, 165 thousand electron tubes, 2,520 thousand resistors, 36 million soldered and twisted connections.

The radar equipment is designed with regard for attaining high operational reliability. Automatic testing and monitoring systems are used for this purpose. The operating load of the parts is 40 percent of the rated load. The important sections of the radar systems are monitored continuously and if they should break down, they can, by the use of switching devices, be replaced by spare sections without interruption of operation.

Considerable work was required for the organization of the communications system. Antennas 18 and 36 meters high are used for the tropospheric communications. For communications from the Thule complex alone there is a double underwater cable, extending 1,120 kilometers across Baffin Bay and 2,000 kilometers to Newfoundland. There are line amplifiers every 65 kilometers on this cable.

From the point of view of combat effectiveness, has the development of such an enormous and expensive system proved its worth?

An analysis shows that the BMEWS system has a number of fundamental shortcomings which put in doubt the capability of this system to fulfil the tasks entrusted to it.

First of all, it should be noted that the idea of creating a system of long-range detection in the form of a radar barrier pointing north is a basically fallacious one. Intercontinental missiles can attack the territory of the USA from any direction. The enormous capital invested by the US in developing the system of radars and powerful warning equipment has been wasted. All of this has now lost its importance, since missiles can fly to the territory of the USA from directions other than that to which the installations are oriented.

This revelation has caused the appropriate reaction. Not long ago the news appeared that, on the request of US Secretary of Defense McNamara, a group of experts is working out recommendations on increasing the capabilities of long-range detection of ballistic missiles. It is expected that the erection of new installations of the BMEWS type will be recommended to detect ballistic missiles approaching from a southern direction. But this problem is extremely complex.

The shortcoming of the BMEWS system, as even the Americans admit, is the fact that it cannot detect missiles launched from submarines or medium-range missiles launched, say, from Cuba. The Americans are also very skeptical about the antijamming capability of the system.

Finally, a vulnerable point in this system is undoubtedly the lack of protection of the radar centers from missile attack. Realizing this, and desiring to compensate in some way for the above-mentioned shortcoming and the unsatisfactory accuracy and resolution of the BMEWS equipment, the US military command was forced to incorporate very complicated and expensive (according to their own estimate) additional target indication and target discrimination radars into the Nike Zeus antimissile defense firing systems being developed.

However, this does not solve the problem, since, by themselves, such means cannot provide sufficient reaction time for a satisfactorily effective accomplishment of the air defense tasks.

Warning means. For early warning, radars can be used that are able to detect targets beyond the horizon. These radars must operate in the shortwave range. The principle of over-the-horizon detection is based on the Kabanov effect.

The Kabanov effect involves the possibility of obtaining a reflected signal from beyond the horizon along the same path as that taken by a straight beam that has been refracted in the ionosphere. The signal reflected from a moving target is detected by the radar against the background of strong reflections from the earth's surface through the utilization of the Doppler effect. Particularly favorable conditions are created for the detection of missiles during their powered-flight phase, when an ionized trail is created that has an effective reflective surface on the order of a thousand square meters.

The operating range of the existing models of the early-warning radars is 3,000 to 4,000 kilometers, but there is reason to expect that, with the further increase of its potential, it may extend up to 6,000 kilometers and, according to some estimates, even up to 12,000 kilometers.

An example of the early-warning radars are those developed in the US under Projects Teepee and Madre.

In Project Teepee, a shortwave (three- to 100-meter) radar was developed for detecting launches of ballistic missiles by the signal reflected from the ionized column of exhaust gases from the rocket engines, as well as for detecting nuclear bursts at ranges of several thousand kilometers. With this radar it is possible to monitor practically all of the missile launches and satellite launches conducted in the USA, as well as atomic tests. Thus, the position of a nuclear burst in the South Pacific was fixed by a radar 13,000 kilometers away. The authors of Project Teepee express confidence in the reliability of detection of the ionized regions at ranges corresponding to the flight ranges of intercontinental ballistic missiles.

In Project Madre in the US a shortwave radar has been developed for the detection of low-flying aircraft beyond the horizon. It is supposed to be used also for the detection of missile launches from submarines. The radar has an operating range of 800 to 4,200 kilometers, depending on the height of the ionosphere, a wavelength of three to 100 meters, a mean radiation power of 100 kilowatts, a beam width of six to 12 degrees in the azimuthal plane, and from 12 to 24 degrees in the elevation plane. The expected range resolution is 16 kilometers, and azimuth accuracy is on the order of three to six degrees. An experimental Project Madre installation is located near Washington. A test model is being built on the shore of the Chesapeake Bay in Maryland.

The main shortcomings of the Teepee and Madre radars are: very low accuracy and resolution, incapability of tracking a ballistic missile in the passive phase of its trajectory, and susceptibility to the effects of ionospheric disturbances and different kinds of interference.

In view of the high value put on the development of an effective early-warning system and the absence of acceptable technical solutions capable of eliminating the above-mentioned shortcomings of ground warning radars, a great deal of attention in the US is being given to the development of an early-warning system mounted on satellites, which would be able to detect a ballistic missile in the powered phase of its trajectory and to determine the approximate direction of its flight and the location of launches. Each such satellite must be equipped with radar and special infrared equipment for detecting ballistic missiles by the infrared radiation of their engines. There is information that the operating range of the infrared rays selected was that which is strongly absorbed by the atmosphere. This gives the possibility of distinguishing spurious signals from ground sources of radiation (blast furnaces, factories, etc.). In this case the ballistic missiles can be detected after they have passed beyond the limits of the atmosphere. One satellite, together with its equipment, weighs about six tons.

In order to ensure scanning of the latitudes of the earth, a satellite must be put into a polar orbit. Twelve satellites with orbits lying in a single plane can produce one "unit cell" of a system that provides simultaneous scanning of a band of the earth's surface more than 6,000 kilometers wide. In this case, six of the satellites of the "unit cell" must rotate in one direction, and six in the opposite direction. This is necessary in order to exclude the interference coming primarily from the sun, but also that from other space objects.

Six "unit cells", i.e., 72 satellites, are required to scan the entire surface of the earth. To do this, the planes of movement of the satellites of each "unit cell" have to be shifted in relation to one another by 60 degrees at the equator.

In spite of certain successes in the development of the equipment for the reconnaissance satellites, the completion of the Midas program, according to the latest information, has been delayed considerably. The reasons for the delay, apparently, are very serious, and it is thus not accidental that the Americans have decided to concern themselves urgently with an examination of the possibility of perfecting and expanding the BMEWS system.

What conclusions may then be drawn on the basis of an analysis of the principles of design and the progress of the development of the antimissile defense radar system in the USA?

The US antimissile defense radar system is designed on the basis of the necessity of guaranteeing the accomplishment of two main tasks: the detection of the launches of ballistic missiles at the moment of launch, and the determination of their trajectories in the ballistic (passive) phase of flight.

The first task is entrusted to the early-warning system, the second to the long-range detection system. However, in view of the unsatisfactory effectiveness and survivability of the long-range detection system, the Americans are forced to incorporate extremely cumbersome and expensive radar means of ballistic missile reconnaissance into the Nike Zeus antimissile defense firing systems being developed.

The development of an early-warning system involves very great difficulties -- the absence of acceptable technical solutions to a number of fundamental problems.

In general, we may say that the combat effectiveness of the system scarcely justifies the enormous expenditures necessary for its development.