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CONCEPTUAL FOUNDATIONS FOR BUILDING A SYSTEM FOR COMPREHENSIVE PROTECTION OF CRITICAL INFRASTRUCTURE FACILITIES FROM AIR TREATS

The main actions of the enemy deep in the country are aimed at destroying critical infrastructure facilities. Effective protection of important facilities requires a comprehensive approach and officials must understand the possible ways and methods of averting air threats to ensure the survivability of protected facilities. The system of comprehensive protection of a critical infrastructure facility is designed to implement a set of measures to reduce the likelihood of damage to the facility as a result of air attack strikes. The article presents the results of the analysis of the main characteristics of air attack weapons, in particular the range and mass of the warhead. The conducted set of studies showed low values of the effective scattering surface of strike weapons in the radar range. The results of modeling detection capabilities, including low-altitude movement routes, are presented. For operation in the interests of direct detection of air targets and target designation for mobile fire groups, a comparative analysis of the capabilities of small-sized radars was conducted. A list of radio reconnaissance means for detecting air targets and target designation for electronic warfare means is proposed. A list of means of radio jamming is proposed as part of the functional countermeasure subsystem. Means of distorting the radar and optical portrait, as well as means of masking objects of protection, are considered. Variants of equipping the fire damage subsystem are presented. To increase the detection range of low-altitude air targets, it is proposed to install radar means on air balloon platforms. The balloon equipment subsystem can also be used to install optoelectronic and acoustic detection means, means of radio reconnaissance and electronic warfare. According to the results of the study, the composition of the system of complex protection of critical infrastructure objects from strikes by enemy air attack means is proposed.

Keywords: *critical infrastructure facility, protection system, air attack means, detection, camouflage, counteraction to air threats.*

INTRODUCTION

During the fighting, the enemy changed the nature of the armed struggle. Currently, the main efforts are focused on the destruction of critical infrastructure facilities of Ukraine (bridges, transport hubs, important industrial enterprises and other important state facilities).

Approaches to ensuring the protection of critical infrastructure (CI) facilities consist of implementing a set of measures to prepare a regulatory framework [1–3], formalizing the characteristics of air attack means [4], forming a threat model [5], studying the revealing characteristics of the facility and the enemy's intelligence capabilities, preparing proposals for improving the protection of the facility [6], substantiating the rational scope of measures and means of protection [7] and ways of practical implementation of protection measures taking into account existing experience and methodological recommendations [8]. The enemy developed the corresponding methodological approaches in the scientific community in advance [9]. Despite the sufficient elaboration, in particular, of the regulatory framework for ensuring the protection of critical infrastructure facilities, the experience of deterring aggression from the first days showed a sufficient level of competence of responsible officials only in the field of control and distribution of financial resources. Responsibility for implementing practical measures to protect facilities was promptly transferred to other military and paramilitary structures. At the same time, effective protection of important facilities requires a comprehensive approach and officials must understand possible ways and methods of averting air threats to ensure the survivability of protected facilities.

The OKI complex defense system is designed to implement a set of measures to reduce the probability of damage to an object due to strikes by enemy air attack vehicles (AAVs), namely cruise missiles and loitering munitions (kamikaze UAVs). Thus, a pressing problem arises in developing methodological approaches to organizing a complex of organizational and technical measures aimed at protecting Ukraine's critical infrastructure from enemy air defenses in conditions of limited resources.

The purpose of the article was to analyze the characteristics of the enemy's strike AAVs, world experience in detecting and countering AAVs, as well as develop methodological approaches to building a system of comprehensive protection of critical infrastructure facilities.

RESEARCH RESULTS

Characteristics of AAVs

For long-range damage, the enemy most widely uses the following air attack vehicles:

- land-, sea- and air-launched cruise missiles of the type 9M727/728/729 (Iskander complex), Kh-101, Kh-59, Kh-69, Kh-22/32, Kh-35, 3M14 «Caliber», 3M22 «Zircon», 3M55 «Onyx»;
- ballistic and aeroballistic missiles of ground and air complexes of the type 9M723 (Iskander complex), type 9-S-7760 (Kinzhal complex);
- loitering munitions (kamikaze UAVs) like the Shahed-131 («Geranium-1») or Shahed-136 («Geranium-2») type.

Closer to the contact line, they are actively used:

- FAB equipped with universal planning and correction modules;
- unified inter-service planning ammunition;
- anti-aircraft guided missiles 5V55 from the S-300 air defense system (various modifications) and 48N6 from the S-400 air defense system (various modifications).

Strike weapons carriers launch them, usually outside the air defense system of the Armed Forces of Ukraine (Fig. 1).

The existing armament and military equipment of the air (missile) defense of the Armed Forces of Ukraine are focused on performing combat missions directly on the line of contact with the enemy (Donetsk, Kherson, Kharkiv directions) and on covering the main administrative and industrial centers of Ukraine (Kyiv, Dnipro, Odesa, Kharkiv, Mykolaiv, etc.) from air strikes. The length of the borders with the enemy is about 2400 km, which determines the unhindered passage of the ZPN into the territory of Ukraine. The list of critical infrastructure facilities of Ukraine is very large, characterized by hundreds of names. Therefore,

covering all critical infrastructure facilities of Ukraine from strikes by existing forces and means is currently complicated.

From the point of view of the ability to detect enemy SPMs by national radar means, they are characterized by indicators of radar visibility, the study of which is carried out by specialists of the Central Scientific Research Institute of Armament and Military Equipment of Armed Forces of Ukraine based on the results of software modeling on the software and hardware complex for modeling electromagnetic aspects of the functioning of AMEs Ansys Academic Research HF. The conducted set of studies showed (Table 1) that enemy SPMs are characterized by a low value of the effective scattering surface in the radar range.

It should be noted that the application of promising methods for detecting AAVs using multi-position passive (semi-active) radars requires improving the methods for studying the characteristics of radar visibility and expanding the characteristics to bistatic or multistatic backscatter diagrams. The effectiveness of the use of each AAVs is

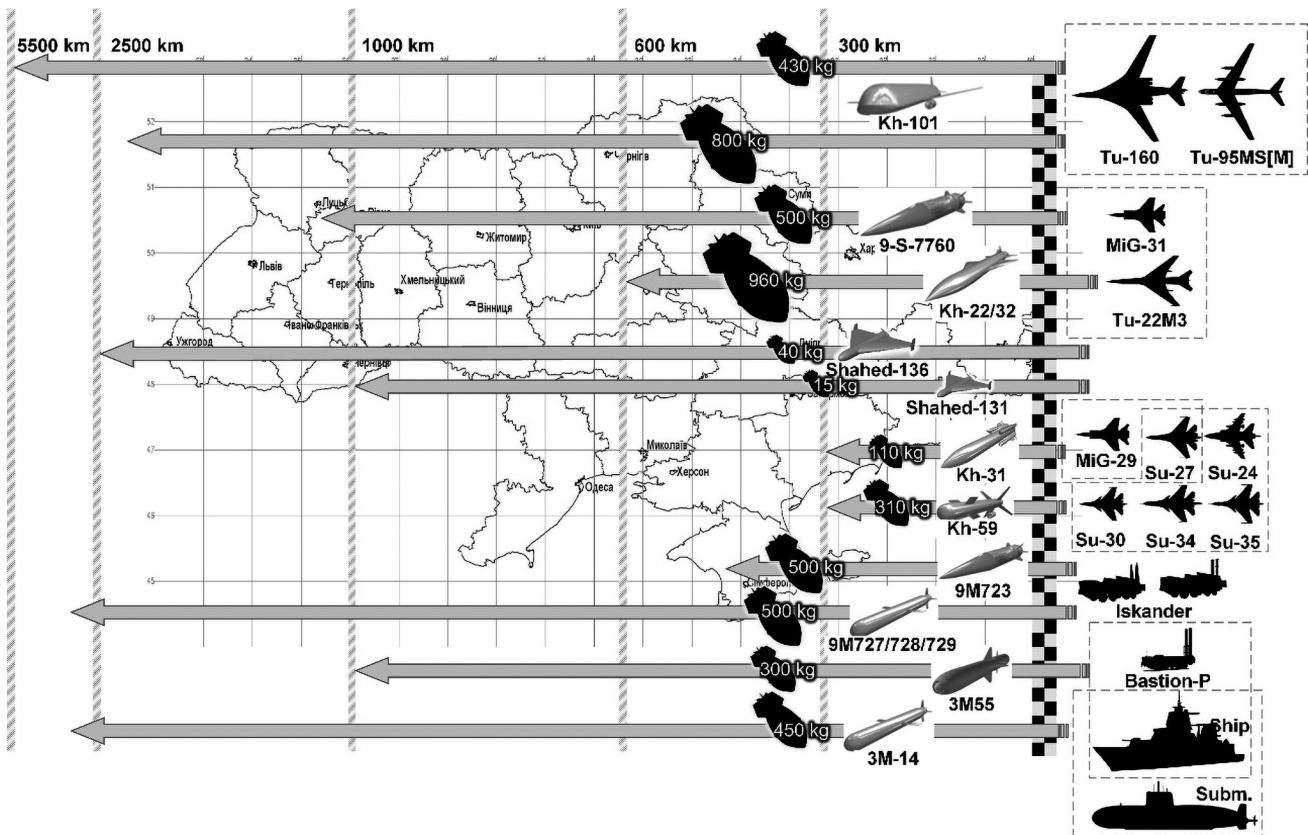


Fig. 1. Results of the analysis of AAVs capabilities

Table 1. Median RCS value [m²] of typical enemy AAVs (f=10 GHz)

Sample	9-S-7760	Kh-101	Kh-55	Kh-22/32	Kh-59	R-37	3M-55	3M-14	UMPK				UPAB-1500B	GROM-1E/2E	UMPB	Shahed-136
									FAB-250	FAB-500	FAB-1500	FAB-3000				
RCS	0,6	0,8	1,7	1,5	0,3	0,8	0,8	0,5	0,1	0,2	0,4	0,8	0,9	0,1	0,1	0,1

determined by a set of sensors from the control system, as well as additional means that help counteract its destruction or disruption of the trajectory of movement and the defeat of the intended target.

Developing the most rational ways to counter enemy AAVs requires improving the air strike threat model by taking into account typical trajectory data, dynamic characteristics of AAVs, target characteristics of heterogeneous sensors from the AAVs, as well as by assessing the main consequences of the regular operation of the AAVs warhead at different indicators of target defeat accuracy.

AAVs detection subsystem

Radar detection. Radar devices are designed for early detection of FPV approaching the protected object, determination of their movement parameters, transmission of received data about FPV to the control and information interaction subsystem.

Low RCS values lead to a decrease in the potential for detecting AAVs by radar stations (Fig. 2).

In addition, the deterioration of the radar detection range of the Cruise missile (CM) is due to the low flight altitude of the missiles (Fig. 3).

Therefore, to improve the potential radar detection range, one can consider installing the radar on high-altitude objects (for example, towers) or on air carriers such as balloons.

The main requirements for radar detection means of AAVs as part of the KI protection system are to ensure high mobility, autonomy of operation and short time for transfer to a combat (transport) position. The low-altitude nature of the AAVs flight may require the installation of a radar transceiver unit at a height (on a mast, tactical tower or structural elements of structures) to ensure the required detection range or placement on a mobile base to quickly increase detection capabilities in the most threatening directions, based on the

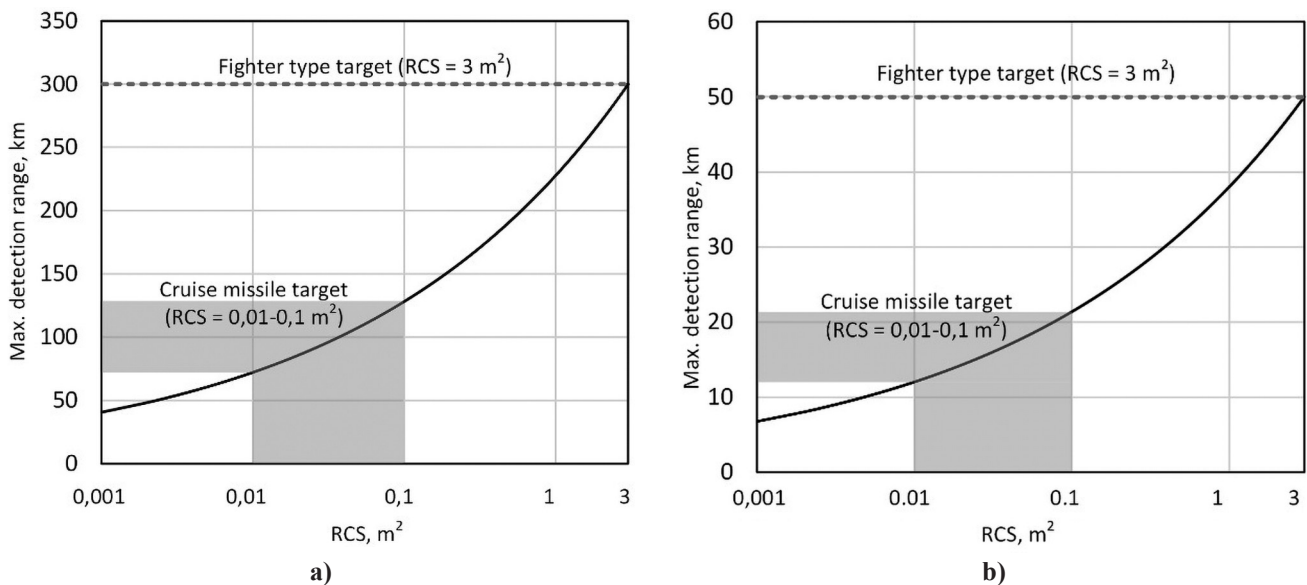


Fig. 2. Results of the assessment of the potential detection range of Cruise missile-type targets compared to a fighter-type target by the long-range (a), as well as medium and short-range (b) anti-aircraft missile system surveillance radar, calculated using the basic radar equation

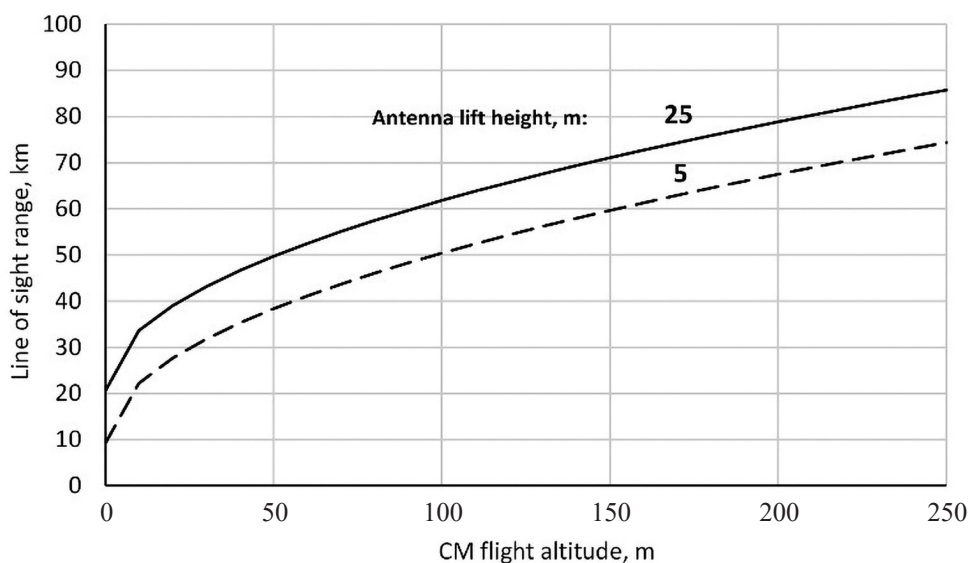


Fig. 3. Results of evaluating the direct visibility range of the radar during flight for different antenna elevation heights

air situation. To simplify installation and maintenance, AAVs detection radars should, if possible, be non-rotating. Such requirements are best met by using modern technologies for constructing solid-state phased (digital) antenna arrays. Possible variants of radars [10] are given in Table 2.

It should be noted that the experience of repelling armed aggression has shown the appointment of radar facilities as priority targets. This requires the development of passive (semi-active) detection means. The current state of development of the theory of construction of passive (semi-active) radar facilities requires the improvement of the scientific and methodological apparatus substantiation of the tactical and technical characteristics of the relevant means of detecting AAVs.

Detection by additional means. Additional means of detecting AAVs:

- optoelectronic means;
- ER-means;
- acoustic means;
- means for detecting launches (including space-based) and monitoring the flight of the CM from partner countries.

The experience of using optoelectronic means of detecting air targets has shown the need to improve optical detection methods in the direction of increasing the speed of space inspection and increasing optical sensitivity.











Increasing the effectiveness of the use of radio reconnaissance means is advisable to be carried out on the basis of the use of a priori data of the threat model. RF-means provide additional target designation to both detection means and electronic warfare means.

It is advisable to choose ER-means in accordance with the importance of the object or group of objects and taking into account the possible integration of data of the radio-electronic environment. Possible options for radio-technical reconnaissance means [11] are given in Table 3. It should be noted that some of the above samples belong purely to military equipment and can be functionally involved in the performance of tasks of protection of the KI.

Joint use of radar, optical, radio and acoustic means of detecting AAVs requires correct integration of coordinate data on the air situation. To perform the tasks of classifying targets and developing recommendations on rational countermeasure options, it is advisable to use elements of artificial intelligence. Thus, for early detection of CM when approaching critical infrastructure facilities of Ukraine, it is advisable to use:

- domestic and foreign means of radar and optical detection of CM;
- foreign means of radar and optical detection of CM based on space (military and technical assistance of partner countries);

Table 2. Variants of small-sized radars for equipping anti-aircraft defense units of the KI

Name	Country of origin	Freq. range, GHz	Azimuth viewing area, degrees	Detection range (RCS 0,01 m ²), km	Coord. recogn. accuracy:		Number of goals that are exceeded	Weight, kg
					distance, m	azimuth, deg.		
ELM-2016NG	Israel	1-2	360 	10	30	0,5	60	b/r
PGSR-3i Beagle	Israel	8-12	6-345 	3	10	0,4	600	b/r
ELM-2026B	Israel	8-12	360 	3,6	30	0,3	100	75
DAiR	Israel	8-12	(1-4)U×110	5	b/r	0,3	10000	1U×27
RPS-42	Israel	2-4	(1-4)U×90	5	b/r	b/r	b/r	1U×30
RPS-82	Israel	2-4	(1-4)U×90	10	b/r	b/r	b/r	1U×58
Spexer 2000	Germany	8-12	(1-3)U×120	4,3	b/r	b/r	b/r	b/r
GO-12	Germany	12-18	360 	4	50	b/r	30	16
ACAR	Turkey	12-18	10-360 	1,9	д/у	b/r	b/r	b/r
FIELDctrl Range	Poland	8-12	(1-4)U×90	5	3	b/r	b/r	b/r
FIELDctrl Follow	Poland	8-12	1U×20	10	1	b/r	b/r	b/r
A422 DRS	Britain	15-17	(1-4)U×90	2,7	60	0,5	b/r	1U×25
PSTAR	USA	1-1,4	360 	b/r	200	2	b/r	b/r
SR Hawk	USA	16,4	360 	4	10	0,2	350	b/r
GA9120	USA	3-3,3	3U×120	2	10	b/r	b/r	1U×41
ARSS	USA	8-12	360 	3	25	b/r	300	19
RDN-170	China	8-12	360	5	10	1	b/r	b/r
Лис-2М	Ukraine	36	360 	1	25	1	b/r	40
112L1 Борсук-А	Україна	36	360 	0,3	25	1,5	b/r	5,5

Note:  – rotational system; b/r – data is being refined.

Table 3. Variants of ER-means for equipping anti-aircraft defense units of the KI

RF-station type	Country	Producer
Wolfpack 210 (WP210), WINGMAN-100	Denmark	MyDefence
Drone Detection System DTS-2458	Estonia	RANTELON OÜ
GES-210	Israel	Elisra Group
AeroScope	China	DJI
AARTOS X9-19 Rack Version Dron Detection System	Germany	Aaronia
RF-360RF	Germany	Dedrone
ARDRONIS-D, PR-100, Argus-M2, DDF119, FSH-20	Germany	Rhode&Schwarz
MUROS-S	Germany	Elettronica Group – ELT GmbH
MSR-W	Poland	PIT
MUR-20	Poland	WZE
Gunica PRP-25M, PRP-25S	Poland	PIT-RADWAR S.A.
TCI 803[S], 903[S]	USA	TCI INTERNATIONAL
AN/PRD-13 (V)3	USA	L-3 Linkabit
KrakenSDR	USA	KrakenRF Inc
DroneFox, Scorpion	USA	WhiteFox Defense Technologies, Inc
Archon-S	Ukraine	Company
RPS-7 «Ingul», Kolchuga-MK	Ukraine	Company
ADMU-12	Ukraine	Company
KVS-UJS, AD-1	Ukraine	Company
FRANEK, TINY SA ULTRA 2.0	Ukraine	Company
TRC 6200-DF	France	Thales Land & Joint System
VERA-E, VERA-NG	Czech	ERA
SRTP	Czech	ERA
Sirius Compact, CRS-8000	Sweden	Saab AB

- domestic and foreign means of acoustic detection of CM (creation of a system of acoustic sensors);
- domestic and foreign means of radio reconnaissance of CM.

In order to detect enemy radars early when approaching critical infrastructure facilities of Ukraine, timely processing of information and issuing information to the control points of the unified state system of physical security of critical infrastructure facilities of Ukraine, it is advisable to consider the option of using domestic and foreign radar detection means of radars on towers and/or balloons, which may be the subject of further research.

Functional countermeasure subsystem.

Electronic warfare means. Reducing the effectiveness of the use of AAVs can be achieved by electronic suppression of radio equipment:

- radio altimeter receiving channels (CM of the type Kh-101, Kh-59, 3M-14);
- receiving antennas of satellite navigation systems (AAVs of all types);
- active seeker (missiles of the type 3M-14, 9M728/729, 3M55, Kh-59, Kh-55, 9-S-7760).

The proposed list of electronic warfare means [12–14] is given in Table 4.

Individual EW means can be considered for installation on an aerostat complex. However, the issue requires additional research. The EW means listed in Table 4 can be

used mainly to counter AAVs. Countering cruise missile-type anti-aircraft missiles currently requires improvement in terms of EW.

Means of distorting the KI radar portrait. Means of distorting the KI radar portrait are designed to create a false situation in terms of radar. The subjects of counteraction are space-based radar means, as well as radar-seeking systems.

The reduction in effectiveness is achieved by misleading the enemy regarding the location of the most important objects (the spatial structure of the KI), as well as by disrupting the acquisition of the radar-homing seeker target (missiles of the type 3M-14, 9M728/729, 3M55, Kh-59, Kh-55, 9-S-7760) by the radar portrait.

It is advisable to install the appropriate means both directly on the KI and near it to deform the general radar portrait of the area. The proposed list of simulators of infrastructure objects in the radar range is given in Table 5–6.

The direction of further scientific research is the substantiation of methods for forming specified levels of radar visibility (both reduction and increase), as well as methods for forming false radar portraits of KI of various composition and size).

Means of distorting the optical portrait of KI (in the visible and infrared range). Means of distorting the optical portrait of OKI are intended for forming a false situation in optical terms in the visible and infrared ranges. The subjects

Table 4. Variants of EW-means for equipping anti-aircraft defense units of the KI

Type of electronic warfare equipment	Country	Producer
DroneSentry, DroneGun Tactical, DroneNode	Australia	DroneShield
J 360 C7/7	Austria	EW Drone Passion GmbH
Sky Net Longbow, Recurve Max, Recurve	Britain	Kirintec Ltd.
L3 Drone Guardian	Britain	L-3 Communications ASA Ltd
SKYPERION	Britain	METIS Aerospace Ltd
Claw C-UAS	Britain	Enterprise Control Systems Ltd.
AUDS	Britain	Blighter Surveillance Systems Ltd.
NIGHTFIGHTER	Britain	Steel-Rock Technologies
Falcon Shield	Britain	Leonardo Airborne and Space Systems
GGJ-100-2-01	Estonia	Rantelon
C-Guard DroneNet	Israel	Netline Communications Technologies
ReDrone	Israel	Elbit Systems
Drone Guard	Israel	Elta Systems Ltd.
Drone Dome	Israel	Rafael Advanced Defense Systems Ltd.
MP807	Israel	Phantom Technologies Ltd.
ADRIAN	Italy	Elettronica Group - ELT Roma
Sky Sweeper	Jordan	Jordan Electronic Logistics Support Co.
Ancile	Canada	Allen-Vanguard
CT-4001PH, PH2	China	R&R Group
ATJ6-120-20	China	Action Technologies Co., Ltd
EDM4S-UA	Lithuania	NT Service
ARDRONIS-R, -P, (-D)	Germany	Rohde & Schwarz
HP-47	Germany	H. P. Marketing & Consulting
XPELLER	Germany	Hensoldt Holding Germany GmbH
Guardion	Germany	Diehl Defence GmbH
HP 47, 3055T, 3962 H	Germany	H.P. Marketing & Consulting Wuest GmbH
MAD-DOS	Poland	MADDOS Sp. zo. o.
ApolloShiel [Portable] C-UAS, RFG Counter-Drone RF Gun	USA, Israel	ApolloShiel
ADEP Blade	USA	Systems & Processes Engineering Corporation
SkyTracker CORIAN / AWAIR / Small Form Factor	USA	CACI International, Inc.
Drone Tracker	USA	Dedrone
ICARUS	USA	Lockheed Martin
Silent Archer	USA	SRC, Inc.
Drone Defender	USA	Battelle
IHTAR, IHAVASAR	Turkey	ASELSAN
Enclave	Ukraine	Company
CEC-N1/N2, Cloud	Ukraine	Company
QUERTUS AD, Vepr, KRAKEN, KSVG-6	Ukraine	Company
Fog, Contour-1/2/3, Nota-SV, Bukovel-AD,-PP, Zahist-ALD, -AL, -AF	Ukraine	Company
AD2, AD2.E	Ukraine	Company
Tornado-4M	Ukraine	Company
Foil	Ukraine	Company
MOROK 3, 4, 5; TOR; MOLOT	Ukraine	Company
HYMO XL, L, M, S	Ukraine	Company
Octave C, Note	Ukraine	Company
Volcano	Ukraine	Company
Galagaz	Ukraine	Company

Table 4. (continued)

Type of electronic warfare equipment	Country	Producer
Ai-Petri SV	Ukraine	Company
Drone Defeater	France	SESP
Counter UAS	France	Thales Air Systems
CerbAir Stationary Unit	France	CerbAir
DRONE SNIPER	France	ITHPP
Airfence 7.0	Finland	Sensofusion
RTX-2000X	Switzerland	Meritis

Table 5. Domestic samples of radar signal reflectors

Imitation tool	Main characteristics				
	Length of the probing signal 6,66 sm			Petal width	
	Maximum RCS values for triangular design (edge length 1 m)	Maximum RCS values for two-sided design (edge length 1 m)	Maximum RCS values for two-sided design (face dimensions 3x6 m ²)	The main one is in a triangular design	Side in double-sided design
Corner reflector «Corner»	8480 m ²	19000 m ²	6000000 m ²	32 deg.	27 deg.

Table 6. Foreign samples of radar signal reflectors

Imitation tool	Main characteristics	
	Maximum RCS values, m ²	Petal width, deg.
Luneberg Lens Reflector (USA)	100	120
	40	100
	4	90
	0,1	90

of counteraction are space-based optical-electronic means, as well as OE-GOS (missiles of the type 9M723, 9-S-7760) and OE-KENS (missiles of the type Kh-101).

It is advisable to install the corresponding means both directly on the KI and near it to deform the general optical portrait of the terrain. The proposed list and tactical and technical characteristics of optical camouflage means are given in Table 7.

The direction of further scientific research is to substantiate methods for sufficient deformation of the optical portrait based on the characteristics of optoelectronic sensors of the AAVs.

Engineering barriers

Engineering barriers are designed to directly stop the approach of the AAVs to the KI structures, as well as to reduce the consequences of the detonation of the AAVs warhead near the KI structures.

Due to the limited quantitative composition of anti-aircraft missile systems, the direction of further research is to

substantiate the possibilities of deploying air-based network barriers based on aerostat systems on the approaches to critical infrastructure facilities.

Fire damage subsystem

If necessary, the KI protection system can be situationally (functionally) involved in the medium and short-range air defense military means. The predominant composition of the fire damage means of the ZPN, which is part of the OKI protection system:

- anti-aircraft small arms (machine guns);
- short-range air defense systems of the ITTEL-1 type (FrankenSAM, USA), «RAVEN» (Great Britain), «Crotale» (France), «Avenger» (USA), SAM «Osa-AKM», SAM «Stormer-HVM», etc.;
- MANPADS of the «Stinger», «Martlet», «Starstreak», «Mistral», «Piorun», «Igla» type;
- anti-aircraft self-propelled artillery installations of the «Gepard 1A2», «SkyneX», ZSU 23-4M-A1 (Shilka) type, etc.;

Table 7. Optical masking devices

Type of camouflage kit	Main characteristics				
	Detection range by optical reconnaissance means, m	KIt weight, kg	Total area, m ²	Size of elements, m	Application temperature range
Optical camouflage kit MKO (Ukraine)	500	60	216	3×6	-45 °C + 50 °C
Deforming painting	b/r	b/r	b/r	b/r	b/r

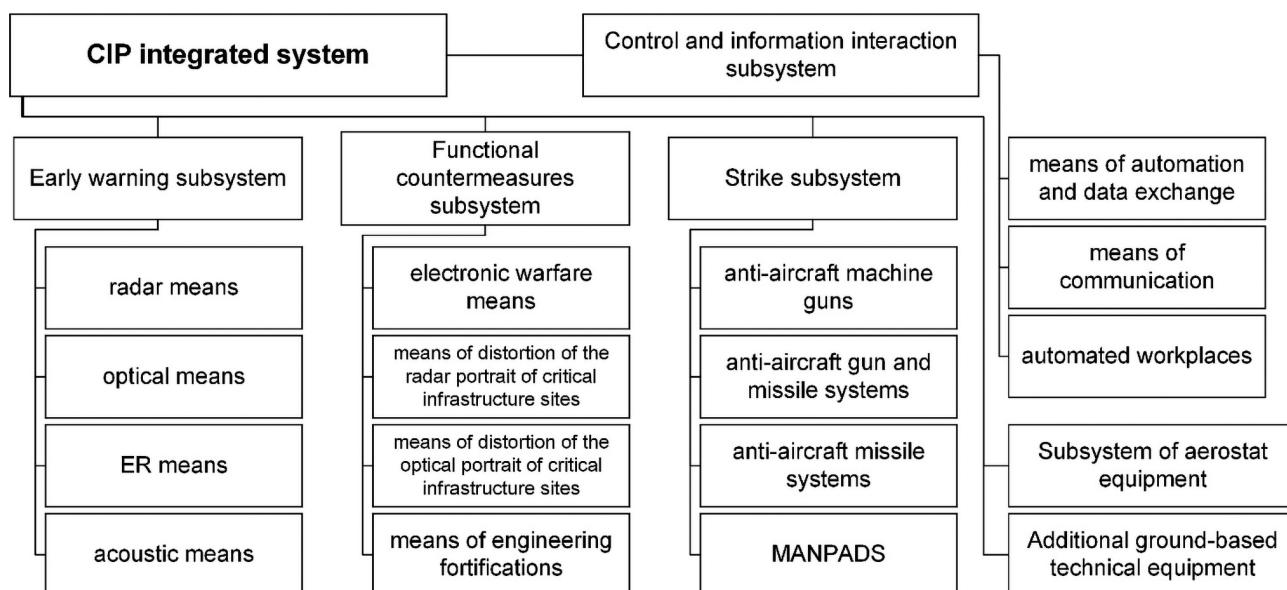


Fig. 4. Structure of the complex KI protection system

Additional means

As noted above, increasing the detection range of low-altitude anti-aircraft missiles can be achieved by installing radar on air balloon platforms. The aerostat equipment subsystem can also be used to install other means: optoelectronic, acoustic, ER and EW. In addition to the specified subsystems, the protection system should include traditional and special equipment (equipment, anti-aircraft defense, repair equipment, maintenance equipment, etc.).

The results of the study on the protection of the air defense system from enemy air attack indicate that the main areas of counteraction to the use of anti-aircraft missiles should include:

- information collection and processing measures, management of the enemy anti-aircraft missile countermeasure system;
- early detection of anti-aircraft missiles when approaching critical infrastructure facilities of Ukraine;
- measures of engineering and radio-electronic support of critical infrastructure facilities to protect against anti-aircraft missile strikes;
- measures of fire destruction of anti-aircraft missiles.

Thus, based on the results of the study, the composition of the complex protection system of the KI against enemy air attack attacks is proposed, which is shown in Fig. 4.

The essence of the functioning of the defense system: information about detected AAVs is summarized at the KI control and information interaction point, its processing and analysis are carried out, targeting is issued for means of electronic suppression and fire damage, electronic suppression and/or fire damage to the AAVs is carried out and control of the execution of tasks to avert danger is carried out. The specified cycle of work is carried out until the threat of damage to the critical infrastructure object is completely eliminated.

CONCLUSIONS

1. The results of the conducted research indicate that the existing capabilities for protecting critical infrastructure from AAVs strikes can be achieved by:

- improving the capabilities of detecting AAVs by installing sensors on high-altitude objects or balloons;
- increasing the quantitative composition of electronic warfare (EW) means (domestic and foreign production);
- developing domestic means of functional destruction of enemy cruise missiles using electromagnetic pulse weapons.

2. Simultaneously with the above measures, it is advisable to increase the level of protection of critical infrastructure objects from means of destruction through a complex of engineering and engineering and technical measures (masking in the optical and radar ranges, creating a false target environment, using initiative developments to interfere with airborne radio-electronic means of cruise missiles, etc.).

3. Work on arranging the positions of protection (defense) means, their final composition, performance characteristics and organization of interaction and information exchange measures require study in relation to the object of protection, taking into account its features.

4. The directions of further research can be defined as the extension of the proposed approaches to small-sized industrial facilities (taking into account their limited capabilities), as well as the computational formalization of the presented components and the study of the effectiveness of complex protection systems of various compositions.

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КОНЦЕПТУАЛЬНІ ОСНОВИ ПОБУДОВИ СИСТЕМИ КОМПЛЕКСНОГО ЗАХИСТУ ОБ'ЄКТІВ КРИТИЧНОЇ ІНФРАСТРУКТУРИ ВІД ПОВІТРЯНИХ ЗАГРОЗ

Основні дії противника вглибині країни спрямовані на знищення об'єктів критичної інфраструктури. Ефективний захист важливих об'єктів потребує комплексного підходу, а посадові особи повинні розуміти можливі способи і методи відвернення повітряних загроз для забезпечення живучості об'єктів захисту. Система комплексного захисту об'єкта критичної інфраструктури призначена для здійснення комплексу заходів щодо зниження імовірності ураження об'єкта внаслідок ударів засобів повітряного нападу. У статті представлені результати аналізу основних характеристик засобів повітряного нападу, зокрема дальності дії та маси бойової частини. Проведений комплекс досліджень показав невисокі значення ефективної поверхні розсіювання ударних засобів у радіолокаційному діапазоні. Представлені результати моделювання можливостей з виявлення, у тому числі при малошумних маршрутах руху. Для експлуатації в інтересах безпосереднього виявлення повітряних цілей та цілевказання мобільним вогневим групам проведено порівняльний аналіз можливостей малогабаритних РЛС. Запропоновано перелік засобів радіотехнічної розвідки для виявлення повітряних цілей та цілевказування засобам радіоелектронної боротьби. До складу підсистеми функціональної протидії запропоновано перелік засобів постановки радіоперешкод. Розглянуто засоби викривлення радіолокаційного та оптичного портрету, а також засоби маскування об'єктів захисту. Представлені варіанти оснащення підсистеми вогневого ураження. Для збільшення дальності виявлення малошумних повітряних цілей запропоновано встановлення радіолокаційних засобів на повітряних аеростатних платформах. Підсистема аеростатного спорядження також може використовуватися для встановлення оптико-електронних та акустичних засобів виявлення,

засобів радіотехнічної розвідки та радіоелектронної боротьби. За результатами проведеного дослідження запропоновано склад системи комплексного захисту об'єктів критичної інфраструктури від ударів засобів повітряного нападу.

Ключові слова: об'єкт критичної інфраструктури, система захисту, засоби повітряного нападу, виявлення, маскування, протидія повітряним загрозам.

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