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METHODOLOGY FOR CONDUCTING PRELIMINARY AND STATE TESTS OF AN AERIAL JET TARGET SET

Metodologia przeprowadzania badań wstępnych i państwowych zestawu odrzutowych celów powietrznych

Abstract: *The article presents a methodology for the implementation of preliminary and state tests on the example of the project entitled "Jet air targets with a programmable flight route" conducted by the Air Force Institute of Technology. The experience in the field of maneuvering aerial targets has allowed for implementation of an aerial jet target set. The further stages of research necessary to implement the set for operation have been presented. Investigations of the aerial jet targets were carried out based on the regulations in force in the Polish Armed Forces.*
Keywords: aerial jet target, state tests

Streszczenie: *W artykule zaprezentowano metodologię badań wstępnych i państwowych na przykładzie projektu pt. „Odrzutowe cele powietrzne z programowaną trasa lotu”. Badania prowadzone były przez Instytut Techniczny Wojsk Lotniczych. Doświadczenia w dziedzinie manewrujących celów powietrznych pozwoliły na wdrożenie zestawu tych celów. Przedstawiono kolejne etapy badań niezbędnych do wdrożenia zestawu do eksploatacji. Badania odrzutowych celów powietrznych realizowane były w oparciu o aktualne przepisy obowiązujące w Siłach Zbrojnych RP.*
Słowa kluczowe: odrzutowy cel powietrzny, badania państwowe

1. Introduction

The military technology research is one of key activities undertaken in order to implement the research object to the Armed Forces [9]. The research object was a prototype of a set of aerial jet targets with a programmable flight route (ZOCP-JET2) intended for training and performance of missile as well as artillery and missile shootings from anti-aircraft sets using radar beams or infrared radiation detectors to guide rockets (missiles) [10]. The ZOCP-JET2 prototype subject to the research included (fig. 1):

1) aerial jet targets (OCP-JET2) – 5 sets;
2) ground control station (NSKL) – 1 set;
3) take-off launcher (WS) – 2 sets;
4) flight coordinator's workplace (SKL) – 1 set;
5) microwave transmission system (SR) – 1 set;
6) preparation and service station (SPO) – 1 set;
7) engine preparation station (SPS) – 1 set;
8) airport transport system (STL) – 1 set;
9) product technical documentation (DTW) including:
   - design documentation (DK);
   - instructions of use (IU);
   - instructions of technical services (IOT);
   - equipment books (KU);
   - technical conditions (WT);
   - software (OPR);
   - training programme for operation and repair personnel (PSP);
   - criteria of service and recovery team training (KW);
   - disposal conditions (WU).

The aerial jet targets (OCP) are remotely controlled by the ground flight control and operation system (NSS) in two modes: internal (instrument) control, without the object visibility, with the use of an on-board flight control and operation system and a data transmission system and control commands (automatic control mode) or (in take-off and landing phases) "manual" (external) control with the object visibility (RC control mode). The aerial jet target take-off [6], flight and landing are performed in the automatic control mode – take-off with the use of a take-off launcher [2], and landing with the use of a parachute system. In special situations, it is possible to perform the take-off, flight within the range of visibility and landing in the RC control mode. Landing in the RC control mode is performed with the use of the parachute system. The control mode selection is performed by the RC control mode operator (RC operator) with the use of a manipulator with a remote-control transmitter [1].

The ground flight control station (NSKL) is the place of work for the operators and the coordinator during pre-flight preparation of the aerial jet target and performance of air tasks.

The flight coordinator's workplace is intended for visualisation of air tasks performed by the aerial jet targets at the command post of shootings based on data sent from the ground control station via microwave transmission system.

The preparation and service station equipment is intended for performing the services and minor repairs of the aerial jet targets. The preparation and service station consists of an engine preparation and service station (SPOS). The engine preparation and service station is intended for determining and archiving the initial characteristics of the drive unit engines of the aerial jet targets and verification of the suitability of engines after the performed flight [3].

The airport transport system is designed for transporting the aerial jet targets from the preparation and service station to the take-off launcher before the flight, as well as placing the aerial jet targets on the take-off launcher trolley and transporting the aerial jet targets to the preparation and service station after landing.

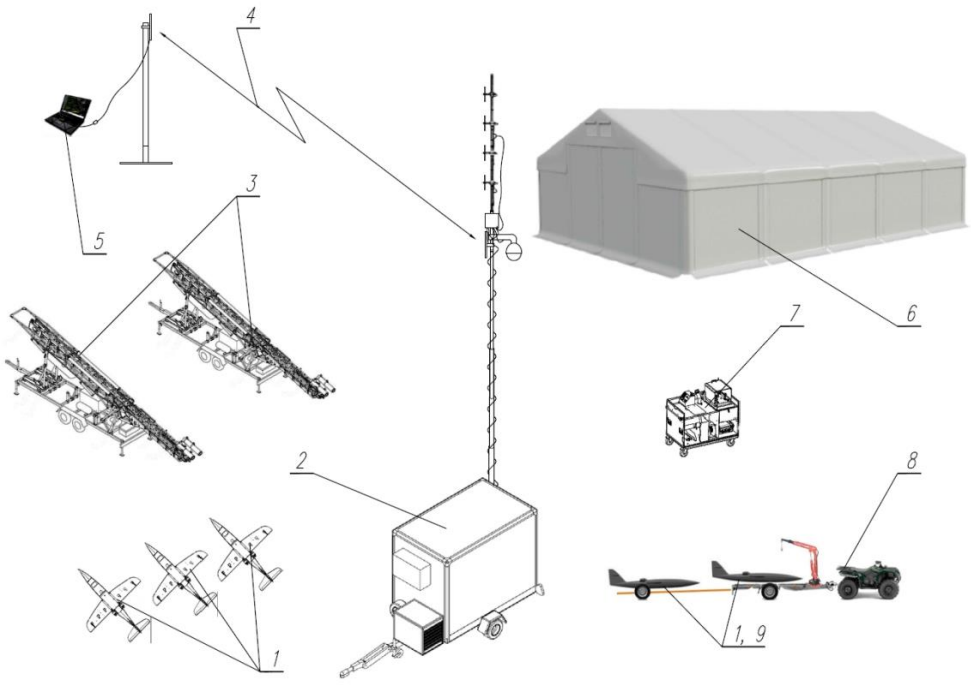

Fig. 1. A set of aerial jet targets with the ZOCP-JET2 programmable flight route

Fig. 2. OCP-JET2 aerial jet target

2. Research methods and scope

The prototype of a set of aerial jet targets was subject to preliminary and state tests (qualification ones – identical name) in accordance with the procedures included in the relevant standards. The prototype was tested in the real operational environment during the operation of anti-aircraft defence forces. The tests were carried out in order to check its basic characteristics included in tactical and technical assumptions (ZTT) in accordance with the research programme [3]. The prototypes presented for state tests were characterised by positive results of preliminary tests and were checked by relevant institutions for compliance with the technical documentation of the product (DTW). The state (qualification) tests were carried out under the supervision of the Qualification Research Commission (KBK). The objective of tests was to check the flight control and operation system of the aerial jet target platforms and determine flight capabilities, performance and suitability of the platform as an imitator of controlled aerial targets with a programmable flight route during the missile shootings of the OSA-AK and KUB sets, in particular:

- checking the compliance of tactical and technical characteristics of the product prototype with the requirements included in "Tactical and technical assumptions on a set of aerial jet targets with a programmable flight route";
- checking the correctness of performing the design documentation of the product prototype submitted for qualification tests;
- checking the conformity of the product prototype performance with the design documentation project;
- assessment of flight capabilities based on real flights of platforms carried out on CPSP USTKA;

- checking the reliability and safety of using the product;
- assessment of the correctness of the applied construction solutions and the development of possible recommendations in terms of the improvement of the construction and equipment and the product operation;
- Determination of the possibility of starting the product serial production.

The state tests were divided into two testing subgroups, these are ground and in-flight tests. The test scope was presented below.

2.1. Scope of ground tests

The ground tests of a set of aerial jet targets with a programmable flight route (ZOCP-JET2) were aimed at checking the correctness of operation of all subsystems of the set. They covered a series of activities that allow to significantly reduce the risk associated with in-flight tests.

2.1.1. JET-2 aerial jet target tests:

The scope of tests of the JET-2 airframe included:

- checking of the airframe geometry, spacing of fastening knots of the aerial jet targets on the take-off launcher trolley and the deflection of flight control surfaces with neutral and extreme positions of a control stick;
- determination of the maximum take-off weight and position of the centre of mass in the fuel amount function;
- checking the operation of the parachute release system;
- checking and assessment of the maximum drive unit thrust;
- checking the operation of the fuel system of the drive unit during the specified climb and descent;
- assessment of the maximum working time of the power supply system;
- checking and assessment of the on-board lighting system;
- checking the operation of a system of infrared radiation sources;
- checking the effective reflection surface of the radar reflector;
- determination of the expected time of restoring the readiness for the next flight on the ground handling station;
- determination of the expected time of replacement of the basic components and systems;
- checking and assessment of technical interchangeability of basic systems and components;
- tests of resistance of the set to the impact of environmental factors.

2.1.2. Ground flight control station tests

The ground flight control station tests included the following activities:
- checking the scope and assessment of imaging parameters in the ground control station (NSS);
- assessment of the possibility of planning the air tasks of the aerial jet targets;
- checking the ground control station operation during the pre-flight and take-off preparation of the aerial jet targets;
- assessment of take-off procedures, the approach to landing and parachute landing in the automatic control mode;
- checking the operation of components of the aerial jet targets during the bench test in the RC control mode and automatic control;
- checking the possibility of ensuring the internal temperature of the ground flight control station at reduced and increased ambient temperatures;
- assessment of functionality of the operators' and coordinator's workplaces.

2.1.3. The microwave transmission system and flight control station tests (SR and SKL)

The microwave transmission system and flight control station test included checking the data transmission range of the microwave transmission system as well as the quality and completeness of imaging the on-board data in the flight control station.

2.1.4. Take-off launcher tests (WS)

The take-off launcher tests consisted in:
- determination of a lead angle of the take-off launcher and an angle of attack of the aerial jet targets in the take-off position;
- checking and assessment of the operation of the take-off launcher during the release of point mass;
- determination of the maximum speed of the release of point mass equivalent to the maximum take-off mass and the time of restoring the re-use capability of the take-off launcher;
- checking and assessment of the operation of the exhaust gas separators.

2.1.5. Preparation and service station tests

The preparation and service station tests included:
- checking and assessment of the refuelling system operation;
- checking and assessment of the lighting system operation;
- checking and assessment of the heating system operation;

– checking and assessment of the operation of the jet engine preparation and service station.

2.1.6. Airport transport system tests

The airport transport system tests were carried out in order to:
– checking and assessment of the operation of transport trolleys;
– checking and assessment of the possibility of towing the transport trolleys and launchers with the use of the Quad vehicle;
– determination of the expected time of transporting the aerial jet targets in day and night conditions.

In addition, the ground tests of the OCP-JET2 system included:
– checking the completeness and assessment of the technical documentation;
– assessment of the construction, producibility and ergonomics of elements of ZOCP-JET2;
– assessment of operational vulnerability, metrological protection and safety of using the ZOCP-JET2 elements;
– assessment of the way of maintenance, packaging, storage and marking of the ZOCP-JET2 elements;
– checking and assessment of the operation of the simulation system for training the ground flight control station operators.

2.2. Scope of in-flight tests

The in-flight tests of a set of aerial jet targets with a programmable flight route (ZOCP-JET2) were aimed at checking the functionality of the system operation during the mission performance, confirmation of the system performance and confirmation of compliance with tactical and technical assumptions ZOCP-JET2.

2.2.1. Tests on the operation of the flight control and operation systems

Tests on the operation of the flight control and operation systems included [4]:
– checking the operation of the airframe and the flight control and operation systems;
– checking the automatic return procedures;
– checking the required maximum operating range;
– checking the operation of the flight control and operation systems in the operating conditions of radiolocation devices and sources of the anti-aircraft warfare (AAW);
– checking the operation of the parachute landing system in the automatic control mode;
– checking the possibility of simultaneous performance of air tasks with the use of two aerial jet targets;
– checking the possibility of performing the tasks at night;
– checking the operation of equipment for night flights.

2.2.2. Tests of flight capabilities and performance

The tests of flight capabilities and performance included:
- checking and assessment of stability and controllability;
- checking the required maximum flight time;
- checking the required climb speed;
- checking the required maximum ceiling;
- checking the required maximum flight speed;
- determination of the climb speed and the maximum flight speed with a built-in system of infrared radiation sources;
- determination of the climb speed and the maximum flight speed with built-in equipment for night flights.

In addition, within the framework of in-flight tests, the average time between failures was analyzed.

3. Research results

As part of the research, a series of tests and checks of the entire system of aerial jet targets [7, 8, 11]. The developed command systems (ŁOWCZA-REGA1 - launchers with REGA 2) and a surveillance system (radiolocation stations and reconnaissance measures located on missile sets) during checking of the JET platforms in the actual flight from various azimuths and at various altitudes allowed to define fire tasks in order to possibly best use the destruction capabilities of the sets and check the service training during the missile combat shootings [5]. The lists of flights performed within the tests were presented.

3.1. The tests in the area of CP SP USTKA on 9-27 June 2014

a) test name: conducting the tests of the flight control and operation system of the "JET" platform and determination of flight capabilities, performance and suitability of the platform as an imitator of controlled aerial jet targets with a programmable flight route during the missile shootings of the OSA-AK and KUB sets, preliminary tests of the prototype JET-2A platform;
b) description of tests: testing of the basic JET2 performance;
   - flight speed of 140 m/s (506 km/h) was achieved at a flight altitude of 2 000 m;
   - the ultimate aerial jet target in the current configuration will exceed 150 m/s (540 km/h);
   - the aerial jet target proved to be a correct imitator of the target for the KUB missile set (one of the design requirements), the aerial jet target was recognisable by the system of guided KUB ground-air missiles, proximity fuses of all three launched missiles fired;

- twin-engine propulsion allowed for the task continuation by the aerial jet targets and its safe return and landing despite the two-time sudden switch-off of one of the engines during the flight (unknown cause);
- a new configuration of the autopilot (along with new algorithms) ensuring precise maintenance of the set flight parameters, was tested, the autopilot is ready for integration with the ultimate airframe of the aerial jet targets;
- a new fuel system concept was tested, the system provides correct power supply of engines in all flight phases with the complete use of the tank capacity, the system was accepted for the ultimate airframe of the aerial jet targets.

Table 1

Sample list of flights

Item	Flight time [min]	H max [m]	V max [km/h]	Max. range [km]	Total distance [km]	REMARKS
1	5	465	322	1.9	15.8	Test flight, autopilot regulation.
2	16	604	344	2.7	79.4	Autopilot regulation, a flight with one operating engine.
3	18	1462	403	25.8	94.5	Flight along the fixed route.
4	14	1897	363	25.4	68.4	Route, return with one operating engine.
5	16	2048	505	30.4	93.8	Flight along the fixed route.
6	9 minutes	1 847 m	506 km/h	26 km	55.3 km	Task flight. Shot down target.

3.2. The tests in the area of CP SP USTKA on 20-31 October 2014

a) test name: tests of the flight control and operation system of the JET-2 platform and determination of its flight capabilities and performance;
b) description of tests: a test flight was carried out testing mainly the automatic take-off;
c) list of flights: Flight No. 1 – JET-2A pre-prototype.

3.3. The tests in the area of CP SP USTKA in the period from 25 May 2015 to 26 June 2015

a) test name: conducting in-flight tests of a set of aerial jet targets with a programmable flight route in the scope of preliminary tests;
b) description of tests: various parameters were studied.

Table 2

Sample list of flights

Item	Flight time [min]	H max [m]	V max [km/h]	Total distance [km]	REMARKS
1	36	1440	476	191.2	Correct flight. Autopilot and fuel consumption control.
2	24	3107	528	146.3	Correct flight. Measurement of the climb speed, autopilot and fuel consumption control.
3	17	3413	535	75.7	JET No. 2. Stall while turning caused by the engine cut-out. Parachute. Landing in the sea.
4	6	868	390	29.6	Stalling of both engines. Successful emergency landing.
5	16	870	434	93	Correct flight. Control of navigation algorithms.
6	30	3675	442	178.8	JET No. 6. Engine stalling at the full height (switch-off at "overspeed" (134 thousand)). Damage to the airframe during landing (no possibility of leaving "to the other circle").
7	1	300	240	6.8	JET No. 4. Very poor climb (low thrust). After switching to Auto, the autopilot was unable to climb. Emergency parachute system activated

3.4. Tests in the area of the Sochaczew Airport on 29 April 2016

a) basis: test programme, factory tests;
b) test name: conducting in-flight tests of the parachute system;
c) list of flights: Flight 1 – JET No. 1.

Failure to release the parachute system, damage to the aerial jet targets and the parachute system.

3.5. The tests in the area of CP SP USTKA in the period from 20 June 2016 to 30 June 2016

a) basis: test programme, the Order of the Director of the Air Force Institute of Technology;
b) test name: conducting preliminary tests of a set of aerial jet targets with a programmable flight route.

Seven flights were performed studying various parameters + one attempt of the JET2B-PW take-off.

Table 3

Sample list of flights

	Flight 1	Flight 2	Flight 3	Flight 4	Flight 5	Flight 6	Flight 7
Task Parameter	Parachute system test	Check of the control systems	Control of the maximum control range	Control of flight endurance	Control of the maximum flight speed and altitude	Automatic take-off and landing. Equipment for night flights	Test with 180 N thrust engines
Flight time [min]	13.7	18	21.7	63.5	32.5	30.3	37
Total [km]	63.1	82.9	120.6	289.8	184.9	177.1	214.7
V_średnia [mean] [km/h]	277	275.6	333	274	342	351	347.9
V_max [km/h]	385	324	476	356	590	511	522
H_max [m]	600	1650	3250	600	6300	3150	3150
Consumed fuel [L]	16	12	19	38.4	21.1	23	31
Max. theoretical time [min]	45	77	57.5	84	79.5	67.9	61.5
Take-off mass [kg]	60	65	74	85	80	81	80

3.6. The tests in the area of CP SP USTKA in the period from 26 September 2016 to 30 September 2016

a) basis: test programme, the Order of the Director of the Air Force Institute of Technology;
b) test name: conducting preliminary tests of a set of aerial jet targets with a programmable flight route;
c) list of flights: 2 flights were performed studying various parameters.

Flights 1 and 2: flight in pairs (JET-2 No. 3 and No. 8), Lot 3: night flight (JET-2 No. 3).

3.7. The tests in the area of CP SP USTKA in the period from 5 June 2017 to 14 June 2017

a) basis: test programme, the Order of the Director of the Air Force Institute of Technology;
b) test name: conducting qualification tests of a set of aerial jet targets with a programmable flight route.
Four flights were performed studying various parameters.

Table 4

Sample list of flights

	Device	Test start time	Test end time	Type of activity/tests
Date				
6 June 2017	OCP-JET2 aerial jet target No. 9	11:56	13:05	A flight of 68.5 minutes was performed, a range of 35 848 m. Data for testing according to the methodology No. 6/BK/N/OCP and No. 2/BK/L/JET2 were obtained. Radar reflector 100%. To be replaced: nose, vertical tail-plane.
07/06/2017	OCP-JET2 aerial jet target No. 11	12:16	12:49	A flight of 33 minutes, ceiling of 5 623 m, 635,2 km/h/ Data for testing according to the methodology No. 3/BK/L/JET2 were obtained. Radar reflector 75%. To be replaced: nose, vertical tail-plane.
07/06/2017	OCP-JET2 aerial jet target No. 8	18:42	19:35	A flight of 53 minutes was performed. The data for testing according to the methodology No. 1/BK/L/JET2 in the scope of checking the operation of the airframe as well as the flight control and operation systems and 4/BK/L/JET2 in the scope of determining the climb speed and the maximum flight speed with a built-in system of 9CH44 type infrared radiation sources were obtained. Two flares were fired. Radar reflector 100%. To be replaced: nose, vertical tail-plane.
08/06/2017	OCP-JET2 aerial jet target No. 8	13:14	13:57	The devices were prepared. A flight of 43 minutes was performed. The data for testing according to the methodology No. 1/BK/L/JET2 in the scope of checking the operation of the airframe and 4/BK/L/JET2 in the scope of determining the climb speed and the maximum flight speed with a built-in system of ICP type infrared radiation sources, calibre of 50 mm (training without firing) were obtained.

4. Conclusion

Within the framework of the research, 30 flights were performed with the use of the JET-2 platform. Based on the conducted research results, as well as the implemented assessment and analyses of the Qualification Test Commission, it was found that:

- state tests of the prototype of a set of aerial jet targets were carried out in accordance with the approved "ZOCP-JET2 qualification test programme", and the entire test scope provided for in the programme was implemented [12];
- methodology of the carried-out tests was correct allowing to study all flight capabilities and performance of the aerial jet target with its system;
- the prototype of a set of aerial jet targets presented for testing was made in accordance with the developed design documentation;
- the prototype of a set of aerial jet targets with a programmable flight route met all the requirements included in the "Tactical and Technical Assumptions";
- the applied design solutions make the set safe in use and operation in the scope defined in the Tactical and Technical Assumptions and on the principles specified in the instructions for use;
- a set of aerial jet targets meets the expectations of the director of military equipment and it can be put into use in the Polish Armed Forces;
- technical documentation for the set meets the requirements of the Decision No. 349/MON of the Minister of National Defence of 20 September 2011 and it is assessed as sufficient for the future User;
- it assumed that the set of aerial jet targets with a programmable flight route, in the process of state tests, received a positive assessment.

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