Radio Electronic Technology

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Front cover – MiG-35 fighter

I am pleased to welcome you at the Radioelectronic Technology!

This Farnborough issue of the corporate magazine covers the range of key industry topics, highlighting our business in Russian avionics and state-of-the-art electronicwarfare technologies.

KRET was established in January 2009 by Order of the State Corporation Rostechnologies as a specialized management company. The Concern united over 100 enterprises pertaining to the most high-tech and innovative industries of the Russian economy.

Presently, KRET enterprises and organizations' activities are related to the development and manufacturing of electronic hardware, means of electronic surveillance, friend-or-foe identification, airborne electronics, and special-purpose measuring tools, as well as circuit couplings, electrical connectors, and cable assemblies.

The enterprises of the Concern are located across Russia, from Saint Petersburg to Vladivostok, and the total number of employees exceeds 66,000 people. Today, the products churned out by the KRET subsidiaries enjoy steady demand on both the domestic and foreign markets.

The successful development of the Concern has enabled it to set new objectives. The ones set for until 2020 have been spelt out by the corporate document titled 2020 Radioelectronic Technologies Concern Development Strategy.

Under the strategy, the top priority is to fulfil the orders gained under the Russian Governmental Defence Acquisition Programme and Governmental Armament Programme on time and in full.

Since the foundation of KRET, we have succeeded in what is most important, having created a dynamic, effectively evolving entity capable of responding in an adequate manner to the challenges of the times.

Nikolay Kolesov,
CEO, KRET

Radio-Electronic Technologies to unveil its new brand at Farnborough Airshow

The Radio-Electronic Technologies Concern, which has completed the consolidation of its key assets, will unveil its new brand to its international partners and customers at the Farnborough air show. The move is in line with the concern's strategy of entering another phase of evolution as a comprehensive supplier of integrated avionics. In accordance with the new business model, Radio-Electronic Technologies will display its best avionics and unique radar and navigation systems designed for latest fixed-wing and rotary-wing aircraft.

As part of its exposition, Radio-Electronic Technologies will unveil its new brand to international partners, the brand intended to highlight the concern's leadership in the radio-electronic industry and make it more recognisable on the foreign market. Today, a head-turning brand and sound communication exercise a heavy influence on added value generation; therefore, the rebranding has been a logical step for the concern to increase its capitalisation in the long run. The rebranding also included renaming: now, the concern's name consists in a compact acronym KRET.

The new brand characterises the company's transition to a new business model of a comprehensive supplier of integrated avionics systems, which is in line with its corporate development strategy. Since its inception in 2009, KRET has been consolidating assets in the radio-electronic industry. Last year, it adopted a long-term corporate development strategy.

In 2013, the company acquired stock of 51 subsidiaries in the radio-electronic industry. Now, it comprises 97 plants, research institutes and design bureaux throughout Russia, which employ upwards of 66,000 personnel.

Another important result produced last year is the early meeting of all of its commitments under the governmental defence acquisition programme to the tune of 40 billion rubles plus. This contributed to a sizeable growth of the company's basic economic indexes. For instance, KRET's gross revenue increased by 16.6 billion rubles to 77.1 billion rubles, which is a 27.3% increase compared to the gross revenue in 2012. The aggregate net profit grew by 3.4 billion rubles to 6.6 rubles, having more than doubled as compared to the 2012 net profit. KRET's net profit margin accounted for 8.6%, which is far better than the performance of several of its foreign and Russian competitors, e.g. Rockwell Collins, Thales, Finmeccanica and Lockheed Martin.

Today, the concern has a domestic and foreign order book exceeding 25 billion rubles and exports its products to 60-plus countries.

In addition, it set up a settlement centre on the basis of Novikombank in 2011. The centre optimises KRET's internal and external cash flows and the amount and cost of foreign borrowing and increases the transparency and effectiveness of the financial and economic operations.

KRET announces double profit in 2013

Today, KRET is a new player on the global market of radio-electronic solutions for government and business, with the company facing bright technological vistas and having a long-term corporate development strategy. The concern offers up-to-date radio-electronic products based on innovative Russian technologies and designed for outer space, aviation, naval and army applications. KRET offers a wide range of products for use in the medical, power generation, transport and other spheres. The company's steady growth and good financial standing bolster its commitment to its global security mission with reliance on the best traditions of the Russian radio-electronic school of thought.

"KRET is the leader of the Russian military and commercial radio-electronics market and a key company of the defence industry", says Rostec State Corporation Director General Sergei Chemezov. "The concern evolves in compliance with its corporate development strategy, which has a direct influence on the increasing effectiveness of its production processes and financial discipline. The concern's subsidiaries annually develop and make unique electronic warfare (EW), identification friend or foe (IFF) and avionics systems. An important result achieved in 2013 is the concern's early meeting of all of its commitments under the governmental defence acquisition programme to the tune of more than 40 billion rubles. This facilitated a considerable increase in the company's basic economic performance.

KRET's gross revenue increased by 16.6 billion rubles to 77.1 billion rubles, which is a 27.3% increase over the 2012 gross revenue. The aggregate net profit grew by 3.4 billion rubles to 6.6 billion rubles, having more than doubled as compared to the 2012 net profit. KRET's net profit margin accounted for 8.6%, which is far better than the performance of several of its foreign and Russian competitors, e.g. Rockwell Collins, Thales, Finmeccanica and Lockheed Martin.

Today, the concern's order book made up of orders placed by domestic and foreign customers is worth in excess of 25 billion rubles.

Radio-Electronic Technologies Concern and Russian Helicopters agreed on setting up advanced helicopter avionics development and production centre

In May 2014, the Radio-Electronic Technologies Concern and Russian Helicopters – both being subsidiaries of the Rostec State Corporation – entered into an agreement on joint development, production and upgrade of advanced helicopter avionics. The partners agreed to establish the Helicopter Avionics Integration Centre. The agreement was signed by Radio-Electronic Technologies Director General Nikolai Kolesov and Russian Helicopters Director General Alexandr Mikheyev.

The Radio-Electronic Technologies – Russian Helicopters joint venture will be a Level 1 integrator developing sophisticated integrated helicopter avionics, ECM gear, weapon control system for Russian-made military, special and commercial helicopters.

The up-to-date development principles, which are relied upon in avionics development, production and delivery, imply that individual electronic components are integrated into a single intellectual helicopter system. The system controls flight and the weapons, monitors the engines and aircraft units, protects the aircraft from external threats and provides flight safety.

"Russian Helicopters is among our key partners on the Russian market in the advanced helicopter avionics segment", Radio-Electronic Technologies Director General Nikolai Kolesov said. "Under the agreement, we will provide it with an integrated solution including the full avionics life cycle support ranging from preliminary design to after-sales support. This 'single-window' approach allows expansion and consolidation of the concern's leadership within its branch, which is fully complying with our corporate development strategy".

The agreement signed today by Radio-Electronic Technologies and Russian Helicopters determines basic organisational steps to be made by the signatories to set up the Helicopter Avionics Integration Centre. In the near future, the parties shall set up a joint task force and begin to devise a business plan and a schedule of the forthcoming work.

"Radio-Electronic Technologies, Russia's major developer and manufacturer of helicopter avionics, is a long-time reliable partner of ours, ensuring uninterrupted delivery of components and systems to the holding company's subsidiaries", Russian Helicopters Director General Alexandr Mikheyev said. "The establishment of the centre will become a new phase of our fruitful cooperation, allowing a reduction in the number of avionics suppliers and in logistic costs".

The joint venture is expected to step up the effectiveness of the design and production cooperation between Radio-Electronic Technologies and Russian Helicopters under programmes of further upgrade of advanced combat and commercial helicopters. Now, the two are already designing the advanced Mi-171A2 multirole helicopter and a sophisticated integrated avionics suite to fit the future high-speed helicopter.

The Radio-Electronic Technologies Concern unveils on the world market the cutting-edge avionics to fit the Russian Advanced Commercial Helicopter (RACHEL)

The Radio-Electronic Technologies Concern of the Rostec State Corporation unveiled the Russian Advanced Commercial Helicopter's sophisticated avionics suite at the 7th HeliRussia International Helicopter Industry Show (HeliRussia 2014) in May 2014. The RACHEL has a 'glass cockpit' using high-resolution displays providing pilots with flight, navigation and other relevant information.

The 21st-century avionics suite for the RACHEL will be among the head-turners of the global helicopter market. The advanced avionics suite has an integrated modular design allowing drastically higher flight safety, enhanced commonality when integrated with all versions of the helicopter (not only the RACHEL, to boot) and a reduction in the cost of the aircraft. Under the integrated modular avionics concept, the RACHEL's avionics suite is based on open adaptive architecture of the airborne computer systems, adaptable to various applications, a common computing environment with the high-performance ARINC-664 (AFDX) interface, and high commonality and standardisation of all hardware and software.

The avionics suite is in accordance with the 'glass cockpit' concept. It relies on wide-screen high-resolution multi-function liquid-crystal displays (LCD) providing the crew with flight, navigation, weather and other relevant information. The avionics allows controlling the helicopter in the horizontal and vertical axes on a pre-programmed route and flying under any visibility conditions.

The avionics suite includes a unique alert feature using the SyntheticVision technology, with flight and navigation information superimposed on the synthetic imagery of the eternal environment. The system alerts the crew to approaching the operating limits, external threats and ground/obstacle proximity at a given time and in the future.

The avionics suite for the RACHEL helicopter is being developed by the Ulyanovsk Instrument Design Bureau (UKBP), a subsidiary of the Radio-Electronic Technologies Concern. In 2013, UKBP successfully completed its part of the research effort dubbed RACHEL Preliminary Design Development and Flying Testbed Development.

Driving force of Russian radio-electronics

The Radio-Electronic Technologies Concern, a subsidiary of the Rostec Corporation, is unique to Russian industry in many respects. Having united many Russian plants, research institutes and design bureaux, Radio-Electronic Technologies Concern has become the nation's major supplier of radio-electronic solutions for the defence industry and commercial market of Russia and the world.

It comprises developers and manufacturers of airborne radio-electronic systems, electronic warfare (EW) and identification 'friend or foe' (IFF) gear, instrumentation, separable electric connectors and other military, commercial and dual-use products.

Radio-Electronic Technologies Concern leads the Russian defence industry in the development of EW systems of ground-based electronic countermeasures (ECM) systems as well as EW gear to deal with the control systems of air-launched and sea-launched weapons.

The unique speciality of Radio-Electronic Technologies is the development and production of components of the IFF system. The latter is a hardware/software complex for automatic identification of aerial and surface vehicles as friend or foe and for gauging their characteristics. The system is designed for monitoring the use of airspace and the national waters and preventing the engagement of friendly aerial or surface vehicles. It includes interrogators, responders, encryption equipment and automatic weapon disablers used in case of a weapon is aimed at a friendly asset by mistake.

The key component of the concern's production programme is the development of radars to fit warplanes and combat helicopters. Mention should be made of the airborne radars developed by the Tikhomirov-NIIP research institute and in full-rate production by the State Ryazan Instrument-making Plant. They are the Bars radar equipping the Russian defence industry bestseller – the fighters of the Su-30MK family, the Irbis radar fitting the Generation 4++ Su-35 multirole fighter and the Zaslon radar upgrade programme intended for the MiG-31 interceptor. Special mention should be made of the N036 active electronically scanned array radar designed by Tikhomirov-NIIP for the PAK FA fifth-generation fighter. It is planned to serve the basis for a radar to be developed to fit the future Russian-Indian fifth-generation fighter under the FGFA programme. It also is worth mentioning the mast-mounted radar for the Mi-28NE Night Hunter helicopter and the radars designed and manufactured by the Phazotron-NIIR Corporation for land-based and ship-borne helicopters.

As a Russian defence industry player, the Radio-Electronic Technologies Concern fulfils government-awarded orders for combat gear development, production and maintenance and for advanced research and development (R&D). The concern is a proactive participant in military-technical cooperation, offering foreign customers its latest defence and security solutions. A wide range of products from Radio-Electronic Technologies is used by panoply of carriers, including space-based ones.

Creating a steady development model, the concern is stepping up its commercial output. In addition to its basic speciality, Radio-Electronic Technologies is actively diversifying its high-technology commercial production, exploring adjacent and all-new markets ranging from household appliances and medical equipment to automated process control systems intended for fuel and energy providers.

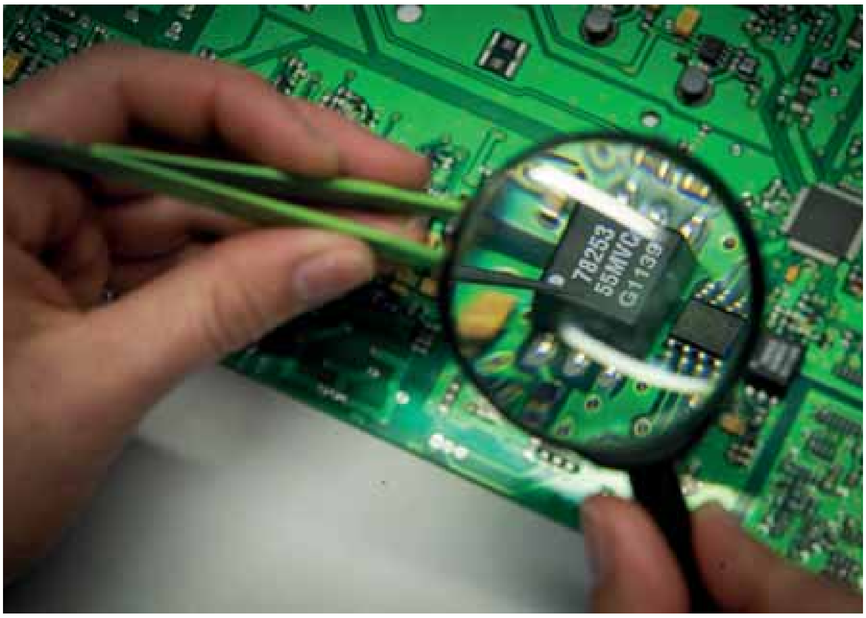
Today, the concern controls 97 research institutes, design bureaux and manufacturing plants in 29 regions of the Russian Federation, with their workforce exceeding 66,000.

The establishment of the concern is a graphic example of Russia's consolidation policy that improves the organisation and streamlining of the production process and facilitates the close cooperation among companies. The results produced are obvious: in 2013, the concern fulfilled the governmental defence acquisition orders ahead of schedule, earned over $6 billion and doubled its net profit over that of 2012.

What does the company owes its success to?

One of its priorities is a large-scale modernisation of its production facilities. At present, 27 of its subsidiaries are running 40 projects under federal modernisation programmes, and about 80 billion rubles will have been invested in the effort by 2020.

Modernisation is aimed at achieving several objectives. Firstly, the use of advanced engineering procedures and up-to-date equipment yields a sizeable labour productivity, product quality and profitability increase and a cost reduction. Secondly, making quality hi-tech



radio-electronics, the concern proves its technological competence and competitiveness on the global market. Thirdly, Radio-Electronic Technologies buttresses its prestige, with its partners, potential customers and the government trusting it more.

Their trust is proven by the cooperation in the avionics and radio-electronics development field with the United Aircraft Corporation (UAC), United Shipbuilding Corporation, Russian Helicopters and many other defence contractors. This creates a driving force propelling the industry forwards.

The other factor of success is sound adequate social and economic policies. The concern's priority is fulfilment of governmental defence acquisition orders, which allows long-term rational operational planning. The workload on the concern's production facilities is clear-cut. Proceeding from it, facilities are distributed and money is invested. The bulk of the concern's income so far falls on government defence acquisition orders. At the same time, efforts are being made to gain a larger slice of the global market.

As far as marketing is concerned, a significant event has been the devising of the new corporate brand that added chastity and strength to the company's image along with openness and readiness for mutually beneficial cooperation. This boosts the investment appeal of Radio-Electronic Technologies for domestic and foreign partners.

An up-to-date market business model contributes to the productivity of companies and manpower's personal interest in good results. It also is very important that every worker is provided with relevant tools of the trade and remunerated adequately. Today, the concern's subsidiaries pursue an effective personnel policy. They employ many young specialists. In addition, the concern cooperates with Kazan Federal University, Kazan National Research Technical University named after A.N. Tupolev and a number of other higher and secondary technical educational institutions throughout the country. This lays the groundwork for high employment, new jobs and continuous expansion of production.

The concern's third pillar is the scientific and technical progress made. Radio-electronics is among the most hi-tech branch of Russia's industry. Therefore, funding R&D is high on the concern's priority list. Now, the military/commercial product ratio stands at 70/30, and the commercial product share tends to increase.

It is a safe bet to say that the concern's present-day products are on a par with the best foreign designs in terms of quality, with some of them being second to none.

From the outset, the concern ensured a large-scale support for all advanced products in demand by the Russian Defence Ministry and economy.

The participants on and visitors of the MAKS 2013 international air show had an opportunity to see for themselves at the concern's stand that Russia's applied science and high-precision industry are not sitting on their hands.

Research has been given a strong impetus. In addition to an increase in funding, research is facing a considerable structural reshuffle. The concern has plans to set up scientific and production clusters, where all plants, design bureaux and research institutes would work literally side by side. The unification like that would both produce synergy and reduce the overall operating costs.

The cutting-edge products Radio-Electronic Technologies is especially proud of include systems intended for future Russian-built planes, e.g. the Zhuk-AE FGA29 and FGA35 active electronically scanned array (AESA) radars developed by the concern's subsidiary Phazotron-NIIR corporation for the MiG-35 fighter and capable of tracking simultaneously up to 30 aerial or ground targets and engaging eight at a same time, with the acquisition range accounting for 200 km.

The concern has developed the unique strapdown inertial navigation system designated as BINS-SP2. It has been integrated with the avionics suites of the Su-35 multirole fighter and T-50 (PAK FA) fifth-generation fighter. The BINS-SP2 performs self-contained positioning and of its carrier and measurement of its movement parameters without having to resort to outside signals. It operates at a temperate bracket ranging from -60°C to +60°C at an altitude of up to 25 km. The BINS-SP2 is rather competitive on the global market in terms of price and performance.

A lot has been done by Radio-Electronic Technologies in the course of development of the avionics suite for the advanced Yak-130 combat trainer. Its all-digital avionics suite allows realistic simulation of the cockpit management systems of various warplanes, e.g. the Su-27 and MiG-29 fourth-generation multirole fighters. All it takes is to activate a relevant program, and the imagery on displays will create the virtual copy required. Moreover, the Yak-130's control system allows simulation of not only the instruments, but an aircraft's in-flight responses as well. This makes the combat trainer a versatile tool of training pilots for different combat planes.

Owing to Radio-Electronic Technologies, the Russian Armed Forces get cutting-edge EW assets and IFF equipment for aerial, ground and naval platforms. The concern's advanced R&D pertains to commercial aviation as well. In particular, the Moscow Institute of Electromechanics and Automatics (MIEA), Ulyanovsk Instrument Manufacturing Design Bureau (UKBP) and Aviapribor-Holding (subsidiaries of Radio-Electronic Technologies) continue the development of an integrated avionics suite wrapped around integrated modular avionics designed for the future MC-21 airliner.

Last year, MIEA completed the design of the PNK-204 integrated avionics suite to fit the Tu-204SM and is now developing avionics to equip the Tu-214. The share of the concern's products in the two avionics suites is to account for 80–85%.

Meanwhile, the concern's personnel are looking far ahead. Advanced solutions will enable the company to consolidate its competitiveness on the domestic and foreign radio-electronics markets in five to 10 years, with microwave electronics, inertial systems, microelectromechanics, microelectrooptics, laser and fibre-optic gyros, liquid crystal and LED displays and high-performance software for radio-electronic systems being regarded as the most promising fields to explore.

An important line of work in the commercial sector is international product certification intended to enable Russian manufacturers to offer their electronics to foreign customers. The concern's efforts to step up its export are in full swing, with the sales volume growing with every passing year.

The concern's development strategy is based on the results of the process auditing of its subsidiaries in 2013–14. Radio-Electronic Technologies determined centres of competence for industrial basic and critical technology development and productionising. In line with its strategic objectives, the concern is implementing an investment programme, using its own money and taking part in governmental programmes. The investment is focused on the modernisation of the current production facilities and creating new ones, key asset and critical competence acquisition, R&D and generation of a technology groundwork in promising spheres.

The concern has managed to become a major player on the market. However, much remains to be done. The Radio-Electronic Technologies Concern evolves, lands new orders, and ramps up the output year in year out; hence, all of its subsidiaries will have their hands full.

Top-notch avionics

Yevgeny Barankin, Director General, Ryazan State Instrument-Making Plant JSC

The Ryazan State Instrument-Making Plant (Russian acronym GRPZ) is a major Russian joint stock company, a subsidiary of the Radio Electronic Technologies Corporation – itself a subsidiary of the Rostec Corporation. For over half a century, the plant has been a specialist in sophisticated radio electronics for airborne and ground-based applications.

The company is in possession of up-to-date manufacturing and technological capabilities. It has been continuously upgrading its production facilities, introducing cutting-edge technologies and maintaining high skills of its personnel to develop and manufacture competitive high-tech products on a par with the highest international standards.

GRPZ's priority is production of airborne radars and fire control systems designed for the modernised MiG-29 and Su-27 fighters and for variants of the Su-30 and Su-35 multirole fighters.

The company performs full-scale production of the Tikhomirov-NIIP Irbis fire control radar system for the Su-35S fighter.

The Irbis is a sophisticated radio electronic system featuring a high degree of automation of airborne and ground target acquisition and tracking, radar mapping, moisture target warning and identification friend-or-foe (IFF). The Irbis has an aerial target acquisition range in excess of 400 km and can track 30 targets simultaneously or engage eight of them at the same time.

Using the requirements specification from the chief designer of the Irbis fire control radar system, the plant has developed and made the SOLO-35.01 and SOLO-35.02 special computers, microwave and low-frequency receivers and active electronically scanned array (AESA) IFF interrogator.

Since 2013, GRPZ has been manufacturing Phazotron-NIIR FGM-129 and FGM-229 airborne radars for the MiG Corporation to fit MiG-29UPG multirole fighters and MiG-29K/KUB carrierborne fighters designed for export.

The company is a participant in the programme on development of an integrated avionics suite for the Future Tactical Aircraft (Russian acronym PAKFA).

GRPZ has teamed up with the Advanced Technologies 2000 close corporation to develop the KNEI-8 and KNEI-24 navigation and electronic display systems intended for Russian and foreign customers. The systems equip the Mi-8, Mi-17, Mi-171 and Mi-35M helicopters enabling them to fly using the data uploaded to the onboard database, receive and process flight and surveillance data, gauge and update the aircraft's current position with the use of inputs from the NAVSTAR and GLONASS navigation systems and exercise visual correction using distinctive reference points.

The company carries on the complete-cycle development of a radar to

Assembly of an Irbis fire control radar phased array antenna

A GRPZ-developed radar onboard a Mi-28N helicopter

Preparations for calibration of the antenna assembly

equip the Mi-28N helicopter, with the efforts including R&D, tests and productionising.

The radar detects ground and aerial targets, positions them, performs mapping and enhances low-level flight safety. The radar's features include its being mast-mounted and a GRPZ airborne computer system housing the low-frequency receiver, analogue-to-digital converter and signal and control processor modules within a single case.

The design documentation of the export variant of the radar fitting the Mi-28NE helicopters has been worked out. The manufacture of the first batch of export radars is under way.

GRPZ performs modernisation of the in-service airborne radar as part of its helicopter-related programmes. Compared to the baseline model, the upgraded radar will be quicker in target acquisition and moisture target measurement. It will get a full-fledged weather radar capability and its positioning accuracy will increase.

The company is developing helmet-mounted displays for rotary-wing and fixed-wing aircraft pilots. They are designed for daytime and nighttime flying and aiming.

Helmet mounted displays generate and show target, flight and navigation information and raster imagery form onboard electro-optical systems to the pilot, while simultaneously sensing the position of the helmet within the cockpit and feeding the resultant data to the onboard computer for the purpose of target designation. Helmet-mounted displays ensure a considerable reduction in target attack time and g-load in air battle and an increase in situation awareness. Irrespective of where the pilot is looking, he has complete flight and aiming information right before his very eyes. Combined with the night vision equipment, the helmet-mounted display ensures night flight, including landing on non-illuminated and austere landing strips and motorways.

The helmet-mounted displays under development can be adapted for use onboard particular aircraft.

The multifunction video image processing systems of the Okhotnik (Hunter) family are the key components of the electro-optical surveillance/sighting systems of helicopters, planes and other combat platforms.

About 15 variants of the Okhotnik system have been developed. They handle the whole range of intellectual video imagery processing tasks inherent in aircraft and ground vehicles. For instance, the ATT automatic imaging infrared/television camera designed for the Mi-28N helicopter improve the crew's vision and performs automatic target acquisition and tracking. In addition, it has been furnished with the additional video image stabilisation capability, which has boosted the quality of imagery and allowed meeting the performance requirements as a whole. The electronic stabilisation capability

Helmet-mounted target designator

has proved to be relevant to other optronic systems as well.

Another product of the Okhotnik family – video image processing equipment – is designed for the electro-optical suite of the PAK FA aircraft, is under development and has the greatest multifunction capability within the Okhotnik family. The equipment receives and digitally processes video imagery, its visualisation from all video sensors of the optronic suite and associated systems, electronic image stabilisation, scaling and rotation, screen capture generation and automatic aerial and ground target tracking.

The Okhotnik family products handling target acquisition and auto-tracking lacked an effective up-to-date guided weapons cuing solution. The solution has been found in the form of the laser beam-riding missile technique implemented using of sophisticated electronic componentry with the use of the latest advances in quantum electronics, lasers and acousto-optics.

Laser guidance systems from GRPZ are high-precision weapon command guidance systems reliant on a programmable spatially-encoded light raster (information field) and using laser beam electronic control technology. The systems feature small size and a high degree of immunity to electronic countermeasures (ECM).

Ultrasonic welding of 15-μm gold wire (AESA section)

Machining facility

Several types of products to fit the Ka-52 and Mi-28N helicopters, armoured vehicles, surface-to-air missile (SAM) systems and other weapon systems have emerged as part of the development efforts in this field. In particular, a system has been developed for the Ka-52 equipped with the Ataka antitank guided missile (ATGM) system. It is designed for use as part of the weapons suite interconnected with the GOES-451 electro-optical sight. The laser guidance system is capable of simultaneous precision guidance of two ATGMs out to 8-10 km with a coordinate selection mean-root-square error of within 0.1 m for the single-channel version and 0.15 m for the dual-channel variant.

In addition to supplying laser guidance systems to equip Ka-52 helicopters, GRPZ is developing weapons precision guidance system for the Mi-28N helicopter upgrade.

At present, the company is using the Okhotnik family for developing, manufacturing and supplying turnkey electro-optical systems to equip various types of SAM systems, particularly, the Kvadrat and Buk-M2E. GRPZ also is developing advanced systems of the kind for the Osa-AKM, Luchnik-E, Strela-10ML and other SAM systems.

GRPZ has pinned its hopes on the implementation of the 2020 Aircraft Instrument Development Strategy devised by the Radio Electronic Technologies Corporation to preserve its stance as an advanced avionics production leader, increase domestic and export sales, retain its traditional niches and explore innovative approaches to combat gear development.

Under the strategy, the company is conducting large-scale modernisation of its production and technological capabilities. If all goes to plan, the plant will productionise up-to-date avionics, including those designed for the cutting-edge PAKFA fighter.

The Ryazan State Instrument-Making Plant has been a defence contractor for over 75 years. Its invaluable experience in sophisticated radio electronics development, refinement of its intellectual and production capabilities, and strengthening of the reliable mutually beneficial relations with its business partners is a guarantee of further success in productionising competitive new-generation products.

Vital objective

Yuri Guskov, Designer General, Phazotron-NIIR JSC

The Radio Engineering Research Institute (Russian acronym NIIR) and Ryazan State Instrument-Making Plant (GRPZ) have enjoyed many years of fruitful cooperation. For about 15 years, they had been subsidiaries of the Phazotron scientific and production association, under which aegis virtually all Soviet airborne radars intended for tactical aircraft have been developed. Although the companies have worked independently in recent decades for a number of reasons, the prerequisites for resumption of their cooperation persisted, having recently become both obvious and necessary. An important step towards the renewed cooperation has been made. GRPZ has launched production and delivery of the Zhuk-M airborne radar developed by the Phazotron-NIIR corporation for fitting the recent variants of the multirole fighters of the MiG-29 family under the governmental defence acquisition programme and for export.

Phazotron has preserved its school of thought, dating back to the Soviet times. It served the basis for refining radar development technologies. In spite of the shortage of funding, the corporation completed the development of and productionised the Kopyo and Zhuk-M slot-array digital radars designed to equip the upgraded MiG-21 and MiG-29 fighters. In the mid-'90s, Phazotron began to explore the helicopter sphere. Our radars equip the Ka-52 scout/attack helicopter and antisubmarine warfare (ASW) and search-and-rescue (SAR) machines from Kamov. The company is Russia's pioneer in development and successful tests of active electronically scanned array (AESA) airborne radar.

Year in, year out, GRPZ has been beefing up its manufacturing and technical capabilities, having turned into a major advanced domestic manufacturer specialising in development and manufacture of high-tech products of mostly military application. At the same time, the plant has been proactive in upgrading its production facilities, introducing latest technologies and honing the skills of its personnel. Owing to a scientific and technical centre of its own, GRPZ is capable of accepting a radar of any degree of complexity from its developer and supporting it throughout its production. A key precondition of GRPZ's success is an efficient workload on its production facilities.

Now, the need has been ripe for both companies to form a single technological platform in the radar system development and production sphere.

Design centre as key element of technological platform

A key element in attaining the objective is to be the establishment of a scientific centre for systems engineering of radars and radar parts and components (hereinafter Design Centre).

The objective of the centre will be development of the following:

- innovative technologies for airborne, naval and ground-based radar applications;

- radar components, e.g. transmitters, receivers, computers and dish, slot, phased-array and AESA antennas;

- transmit-receive (TR) modules;

- monolithic integrated circuits developed, inter alia, by means of the 3D technology and nanophotonics.

An important line of work to be pursued by the centre shall be the testing of assembly and installation technologies for the developed products with the use of relevant software.

The most efficient way to set up the Design Centre is to modernise the scientific, scientific-technical, design and experimental divisions of the Phazotron-NIIR corporation and optimise their operation. The efforts should be focused on the development of cutting-edge airborne AESA radars and their components, including TR modules. The key precondition is that end-products must rival the best foreign designs, pass comprehensive laboratory and full-scale tests and be tested fully for it to enter full-rate production.

Core divisions of Design Centre

Information and Analytical Division

Its principal task is to create and maintain a database of the existing and in-development foreign and domestic radars operating in the basic wavebands (Ka, X, S and L), their components, characteristics, circuitry, hardware and software. Based on the data, the division will work out the configuration of future radars promising enough for the Design Centre to develop. Chief designers should be responsible for devising an issuing the requirements specifications for specific radars.

Integrated scientific and design division

Designing will be its preserve. Based on requirements specifications, its sections and laboratories will design basic components of a product, such as transmitters, receivers, TR modules, antenna arrays, computers, converters and power supply and cooling systems) and integrate them, ensuring the operability of every component and the product as a whole through calculations and lab tests. It should be stressed that the division will operate based on a Phazotron-proven baseline commonised radar development methodology, which strengths include modularity, open architecture, circuitry solution commonality and, hence, a reduction in maintenance costs. The division will have to learn to make digital design documentation fully prepared for full-rate production. An important part of the division will be software development and algorithm modeling.

Advanced technology and innovation division

It will play the principal part in development of competitive products through continuous influx of advanced technologies. It will be tasked not only with seeking innovative solutions and developing advanced technologies, but also, what is very important, with ensuring effective productionising of advanced designs through comprehensive lab tests. To design TR modules for AESAs, we have virtually learnt to use the Low-Temperature Co-fired Ceramic (LTCC) 3D technology and are mulling over the transition to laminar thin films. Another very promising line of work is nanophotonics that is supposed to be pursued by the centre.

Scaled-down modelling division

The division is designed for proving the operability and characteristics of the products developed. The division will be based on the stands of the chief designers (scaled-down modelling complexes), where modelling, simulation and testing of radar operating modes, which exceed 70 as far as present-day radars are concerned, will be conducted with maximal realism. At present, the bulk of such work is down at test benches of contractors, and we have both to pay for that and to provide equipment to fit the test benches at a considerable expense we have to run up. The overwhelming majority of components intended for test benches of the centre will be made by GRPZ using Phazotron-NIIR's documentation.

CAD system as pillar of Design Centre

The key precondition of the Design Centre's productive operation is the coverage of all of its core divisions by an intricate computer-aided design (CAD) system. All engineer workplaces are to be furnished with advanced computers and software required for quality timely fulfilment of tasks assigned. For instance, access to the circuitry solution section of the databank will enable an engineer to program several hundred commands daily, as is done by major foreign companies, while the standard was just three commands per day just a few years ago. A sophisticated radar spares and components section will ensure quick and accurate enough response to a customer inquiring what kind of radar will be optimal to meet his requirements and limitations. There is a complete understanding that the CAD system should be end-to-end, rather than local. The Design Centre's hardware and software should also be compatible with the similar hardware and software of its contractors.

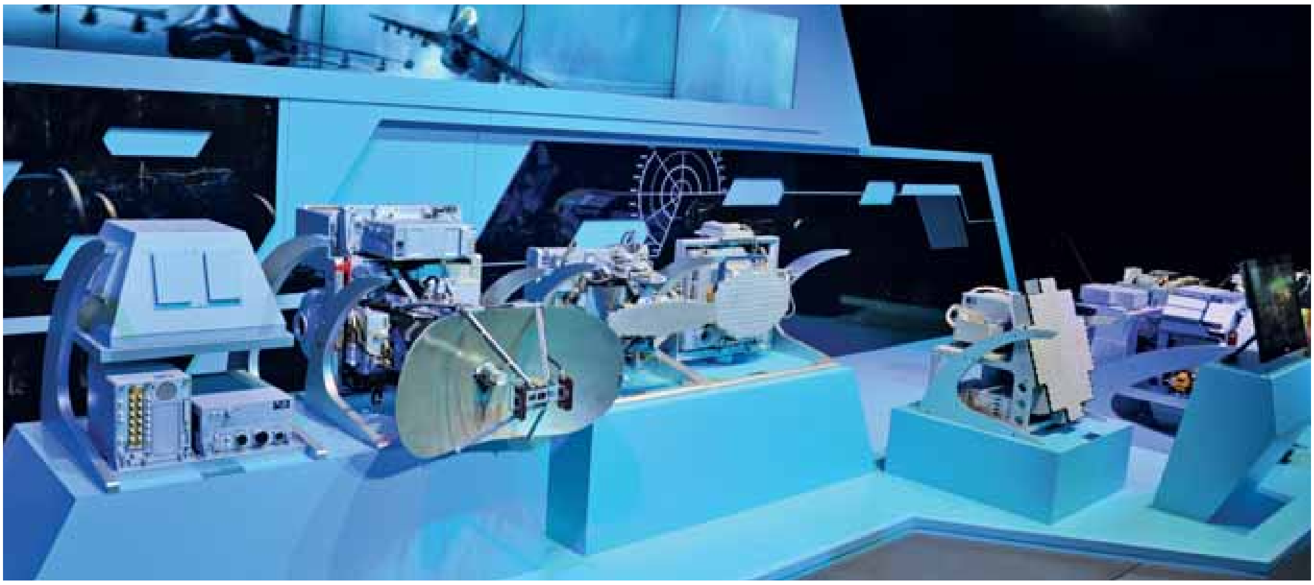
It is necessary that the CAD system also covered the research divisions developing the radar hardware as part of the R&D efforts or devising the design documentation as well as software developing and algorithm modelling divisions and chief designer stands. The radar software development divisions are subject to being furnished with workplaces provided with computers and specialist software, and software modelling and debugging equipment as well. The chief designer stands should be able to debug and comprehensive test of all radar characteristics.

In addition to the divisions immediately involved in R&D, there should be developed support infrastructure, including the metrological service to perform expert examination of the design documentation and hardware and to test instrumentation. It should also include the master manufacturing control system, mechanical supervisor office, chief engineer office and standardisation, commonalisation and normal inspection services.

Certainly, there will be the assembly area established. Radar prototypes for scaled-down modelling bench tests are supposed to be made by GRPZ using the documentation provided by Phazotron-NIIR, because the plant is fully outfitted for the work of the kind and has gained a wealth of experience in cooperation. Providing the Design Centre with a prototype manufacturing facility able to shoulder the critical volume of prototype manufacture work seems to be very relevant.

Maximal effect

The establishment of the Design Centre will ensure the design and development of top-notch radars fully fit for full-rate production. This will be achieved through developing parts of a product and through assembling and testing the product as a whole, including calculations, algorithm generation, lab tests, scaled-down modelling and integration of scientific and design efforts based on the end-to-end CAD system. It is worth mentioning that by the time the development of the parts of a product kicks off, there will have been the complete understanding of



Phazotron-NIIR corporation exposition at MAKS 2013 airshow what kind of electronic componentry will be used, since the requirements specifications for the product, its components and electronic componentry are worked out at the same time.

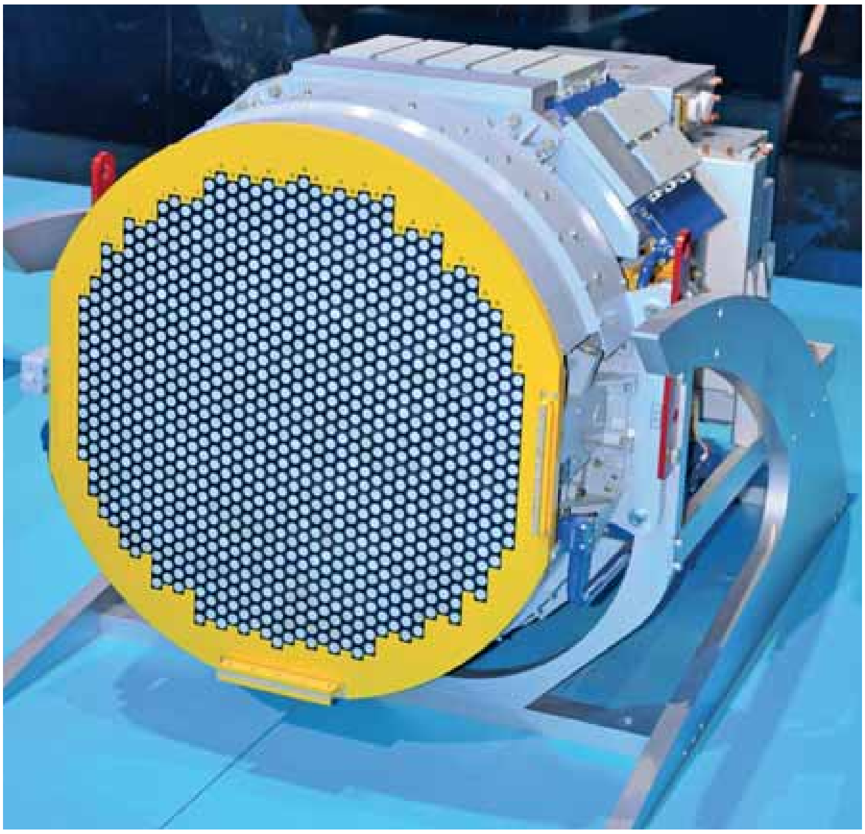
The Design Centre having the information and analysis, integrated scientific and design, advanced technology/innovation and scaled-down modelling divisions will ensure the focus on the most promising approaches and development of the technologies, which introduction will maximise the technical and economic effect.

The centre will heavily influence the development and improvement pf Phazotron-NIIR's personnel and capabilities. Interesting creative work, top-notch workplaces and the opportunity to cutting-edge technologies for design work will certainly woo both young engineers and highly skilled mature personnel, whose shortage has been acute both at Phazotron-NIIR and throughout Russia's radio electronics industry.

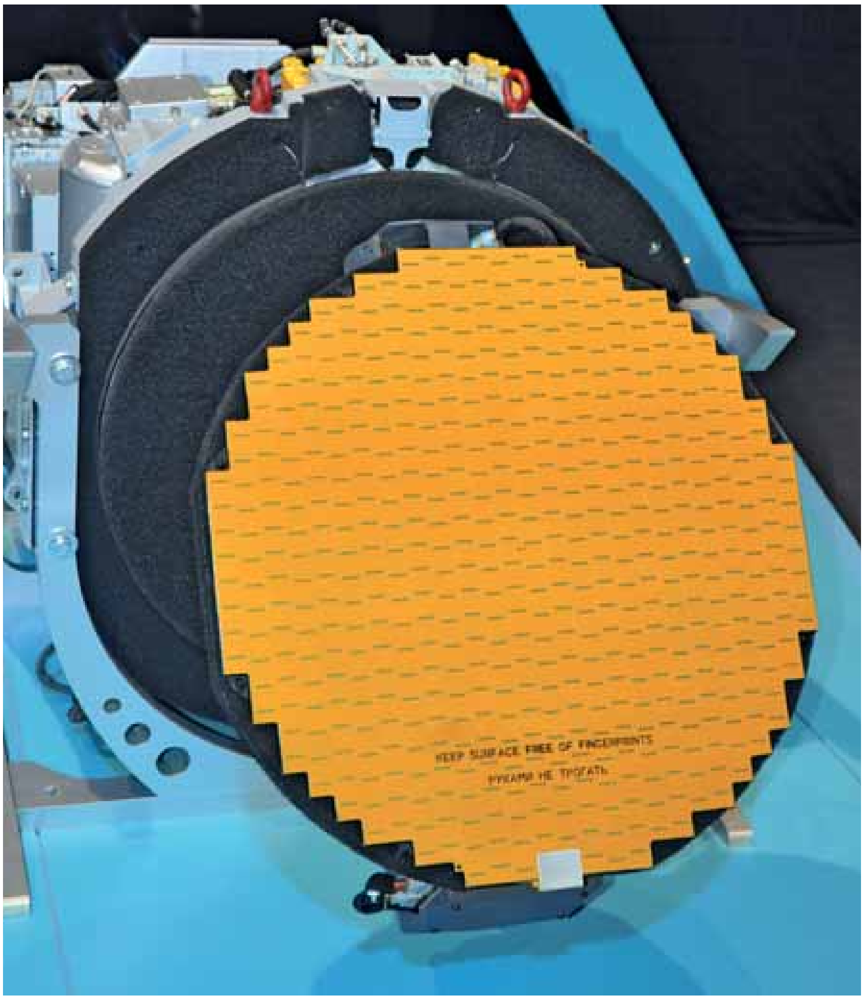
Phazotron-NIIR has proven its ability to develop radars rivalling the best foreign designs by having developed its Kopyo and Zhuk airborne radars. We are the first Russian company to have developed a working example of AESA radar and proved via flight tests its fitness for its main application – the use of guided weapons. Moreover, the radar, designated as Zhuk-AE, has both matched the dimensions of the organic Zhuk-ME radar and retained its power supply and cooling systems. The radar's benefits in all respects are obvious.

The simplest and most economically sound solution is to build everything needed for the Design Centre from scratch, as was done by China's Nanjing Research Institute of Electronic Technology. This is hardly feasible in Moscow. We know what should the centre to be fitted with and what area it requires. The Design Centre compound should ensure optimal operation and interaction of its core divisions through a reduction in the time and efforts irrelevant to technology and product development.

It would be extremely hard to develop top-notch competitive products with the optimal rate of innovative and time-proven technologies. Hopefully, the joint efforts by GRPZ and Phazotron-NIIR, supported by the Radio Electronic Technologies corporation will make it feasible to attain this vital objective.



FGA29 AESA radar



Zhuk-ME radar

Advanced development by Tikhomirov-NIIP JSC: special and commercial radar systems

Gennagy Kaufman, scientific Secretary, Tikhomirov-NIIP JSC
Andrey Vitsukayev, department head, Tikhomirov-NIIP JSC

Combat gear development is a complex multifaceted process combining both revolutionary breakthroughs and subsequent evolution that maximises the use of the progress made. A reasonable combination of 'revolution' and 'evolution' has been recognised as the optimal way of combat and special gear development by major powers. Our institute – Joint Stock Company "V.Tikhomirov scientific research institute of instrument design" – a national leader in aircraft weapons control systems and medium-range surface-to-air missile (SAM) systems for the Army – is a stickler to the approach. For over half a century since its inception, the two lines of work in the institute has run in parallel, complementing and refining each other.

To date, the institute has established a unique scientific and practical school of thought dedicated to the development of electronically scanned array radars.

The development was such systems kicked off in the late 1960s, when the institute took an extremely daring, revolutionary decision to develop the Zaslon fire control system based on the passive radar array. The task was extremely difficult and was taken on with regard to an air defence fighter for the very first time in the world. The MiG-31 equipped with the Zaslon fire control system capable of simultaneous acquisition of 10 targets and simultaneous engagement of four of them entered service in 1981. At the time, there was no US or European fighter to rival it. The aircraft remains the most effective warplane in its class. Despite its rather advanced age, the fighter has retained plenty of upgradeability of the fire control system (Fig. 1) in the first place. For instance, in 2013, there were final flights as part of the remedial action resultant from the official joint trials of the modernised MiG-31BM interceptor fitted with the Zaslon-AM fire control system and advanced long- and medium-range air-to-air missiles. About 50 MiG-31Bs have been upgraded to MiG-31BM standard and have been used by the Russian Air Force.

Fig. 1. Zaslon fire control radar

The electronically scanned array radar and technology development by the institute has allowed the emergence of the Bars airborne fire control radar to fit the Su-30MKI multirole fighter (Fig. 2).

The Bars is a multifunction multimode coherent X-band radar system with the passive phased array. It is mounted on the electro-hydraulic tracking actuator. This allowed a considerable increase in the scan area. Its open architecture allows its further modernisation through enhancing the tactical and operating characteristics.

The Bars from Tikhomirov-NIIP fits about 250 Su-30MKI, Su-30MKM and Su-30MKI(A) fighters successfully operated by the Indian, Malaysian and Algerian air forces. The radar has passed all relevant phases of the trials, has been tested through and through and can handle all of tasks assigned to it.

Now, the Irkut corporation is fulfilling two contracts for 60 Su-30SM aircraft for the Russian Air Force, and the first order for the aircraft of the type has been recently awarded to the company by the Russian naval aviation. The plane designed for the Russian Navy is a Su-30MKI derivative, with its radar system having been derived from the Bars.

The 'Russianised' version, designated as Bars-R, embodies a number of improvements in line with the Defence Ministry requirements is more capable than its export-oriented predecessor. Last year, we successfully completed out portion of the special joint flight tests of the Su-30SM, and fighters carrying our Bars-R radar are in service now.

Another new design from Tikhomirov-NIIP is the Osa small-size multifunction multirole phased-array fire control radar (Fig. 3).

The Osa is designed to equip light multirole fighters and future combat trainers. In the air-to-air mode, the Osa has the all-aspect, look-up/look-down head-on/pursuit target acquisition and tracking capability. In the air-to-ground mode, it performs real-beam Doppler beam-sharpening focused-aperture mapping and simultaneous tracking of two surface targets and selection of ground moving targets.

The Osa is an X-band radar with a power consumption of 4.3 kWA, a weight of 120 kg and a volume of 256 dm^3.

The 40-plus-year development of phased-array radars has resulted in a latest of Tikhomirov-NIIP's designs – the Irbis fire control radar intended for the Generation 4++ Su-35 fighters (Fig. 4).

The Irbis embodies the best solutions worked out in the course of the development of the Zaslon, Bars and Osa.

The Irbis, which is part of the integrated avionics suite of the Su-35, performs an extremely wide range of tactical and auxiliary tasks, including the following:

- acquisition and tracking of radiocontrast and radio-emitting aerial and surface targets;
- identification friend or foe (IFF);
- target recognition and classification based on their radar signatures;
- resolution of aerial targets in tight packages;
- low, medium and high-resolution mapping;
- image freezing and the carrier's own position display;
- low-level flight information support in the nap-of-the-earth mode;
- moisture target acquisition and assessment;
- issuing relevant data to the avionics suite and receiving data from it in line with the data communication protocols available;

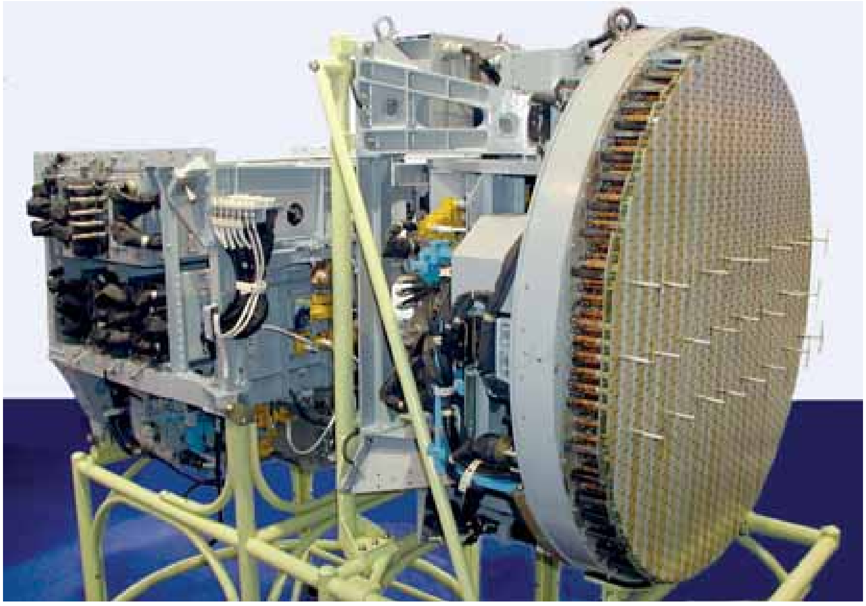


Fig. 2. Bars fire control radar

Fig. 3. Osa fire control radar

Fig. 4. Irbis fire control radar

Fig. 5. AESA multifunction radar

- interaction with air-to-air and air-to-surface active and semi-active radar-homing guided missiles;
- operation as a simulator.

In addition to manned fixed-wing and rotary-wing aircraft, potential carriers for the Irbis radar are unmanned aerial vehicles (UAV) of various applications, including strategic cruise missiles, air-to-air and air-to-surface guided missiles, and battlefield and short-range ballistic missiles.

The flight tests of the Su-35 carrying the Irbis radar proved the target acquisition range unmatched by any other Russian and foreign production or prototype fighter.

The Irbis has been in full-rate production by the State Ryazan Instrument-making Plant (Russian acronym GRPZ). At present, the radar equips more than two dozen production-standard Su-35S warplanes delivered to the Russian Defence Ministry under a contract for 48 fighters of the type.

Today, the key order being fulfilled by the institute is the development of an active-phased-array-based multifunction radar system (Fig. 5) to fit the future fifth-generation fighter.

The effort involved a radically advanced technology level, which will beef up the radar's capabilities by far. On the other hand, to attain the level, the developer has to overcome colossal problems, given the stagnation of the Russian electronics industry of the past 20 years. While in the '70s-'80s, the institute was the uncontested world leader in phased-array radar development, it has to take great pains now to catch up with its foreign rivals from an unequal starting position. Nevertheless, progress has been made, and the scale of the work is increasing owing to a contract signed with India interested in the co-development of a future multirole fighter.

To date, we have made as many as six front-mounted AESA radar sets earmarked for the fifth-generation PAK FA fighter. Two are used for bench tests conducted by us and by the Sukhoi company to test advanced operating modes. The other three have been delivered to the customer to equip the third, fourth and fifth flying prototypes of the PAKFA. The flight tests on the third prototype, T-50-3, including the activation of the AESA, commenced in summer 2012. The aircraft has completed the bulk of the AESA flight tests. In addition, the fourth PAKFA prototype (T-50-4) has been flying in Zhukovsky since last spring, having completed a number of tests of our radar. Very recently, the T-50-5 – the third prototype fitted with our AESA – has launched test flights in Zhukovsky. Thus, there are as many as three PAKFAs equipped with our radars in the fight trials, with the total number of flights, on which the AESA was switched on, being about a hundred.

Most of the flights have been successful. The main result produced is the stable operation of the AESA radar in all air-to-air and air-to-surface modes from the outset.

Now, we are conducting bench tests of the early prototypes of side-looking AESA radars. Soon, one of them will be mounted on a prototype PAK FA. In addition, there also will be L-band AESAs set in the slats of the fighter. Thus, the next four PAK FA flying prototypes will have the complete multifunction integrated radar system, including forward-looking and side-looking AESAs and L-band AESAs.

The expertise gained from phased-array airborne radar development has been used successfully in the development of the Buk mobile multirole medium-range SAM system.

The key radar of the SAM system is a multifunction phased-array radar capable of acquiring and tracking 10–12 targets and engaging four of them simultaneously. The radar and the missile launcher can be mounted either on a self-propelled tracked chassis (Fig. 6) or on a self-propelled wheeled one (Fig. 7).

Overall, the Buk SAM system is capable of repealing a massed air raid by simultaneously engaging up to 24 targets attacking from different aspects and from different altitudes. The targets for it to kill include battlefield ballistic missiles, strategic and tactical warplanes, cruise missiles, helicopters, including hovering ones, and small-size aircraft, including unmanned ones.

A further derivative of the Buk is the Army SAM system designated as 9K317M. It completed its official tests last year, and the manufacturer has been awarded the first order by the Russian Defence Ministry.

As far as commercial products are concerned, Tikhomirov-NIIP JSC develops and produces automatic control systems for subway and commuter trains. The Moscow and Sofia (Bulgaria) Metro trains have been using the Vityaz-1 and Vityaz-1M automated control, diagnostics and traffic safety systems since 1998 and 2005 respectively. Russian Railways JSC orders touchscreen displays and software for its automated train control systems from the institute.

Fig. 6. Multifunction radar on the self-propelled tracked chassis

In 2000, the institute teamed up with several organisations of the Russian Academy of Sciences to develop hydro-acoustic systems, paying for the development out of pocket. To date, Tikhomirov-NIIP side-looking sonars, interferometric sonars and parametric surface analyzers are operated in many seas by such customers as Lukoil JSC, Gazprom JSC, RusGidro JSC, Federal Maritime and Riverine Transport agency, Emergencies Ministry, etc., and South Korean customers as well.

Mention should be made that the institute has completed research into the feasibility of using electronic beam steering in sonars.

The participation in the 9th Bow to Great Victory Ships Expedition in May 2013 was a milestone event to Tikhomirov-NIIP. The expedition was aimed at searching for sunken Soviet submarines. The search resulted in the finding of the S-9 submarine that hit a mine in 1943 and the 84-cannon Lefort ship that sank in 1857.

Fig. 7. Multifunction radar on the self-propelled wheeled chassis

Airborne radar family design concept and its implementation

Yuri Guskov, Designer General, Deputy Director General for research, Phazotron-NIIR corporation
Oleg Samarin, Chief, research division, Phazotron-NIIR corporation

The fighter aircraft radar (commonised airborne radar) family design concept emerged in the Soviet Union in the late 1970s, when V.K. Grishin, general designer of the Phazotron scientific and production association, suggested that commonised airborne radars be developed to fit the MiG-29 and Su-27 fighter jets. At the time, the Phazotron scientific and design association (it was dubbed Phazotron scientific and production association in 1976) comprised the Radio Engineering Research Institute (Russian acronym – NIIR), Instrument Design Bureau (now Tikhomirov-NIIP company) and Moscow-based Kulon design bureau. The former two launched independent airborne radar development programmes for the aforesaid aircraft. The resultant airborne radars consisted of commonised units and differed, essentially, in the dimensions of their antennas only. For the first time, the airborne computers of the radars were developed as an airborne digital computer family. The computers differed in the read-only memory (ROM) capacity and, hence, in design. The fighter radars Phazotron developed later on were commonised too.

The dissolution of the Phazotron scientific and production association along with many other scientific and production associations in the '90s, coupled with the subsequent go-it-alone approach of the research institutes, resulted in the collapse of the airborne radar family design concept. However, once devised, the concept of commonised airborne radar to fit fixed-wing and rotary-wing aircraft has continued to evolve at Phazotron-NIIR.

The scientific, technical and technological progress made by the corporation over recent years has enabled it to formulate the airborne radar family design concept based on the market demand and up-to-date capabilities available to the corporation.

Airborne radar family design concept

The present-day airborne radar family design concept should meet the following requirements:

- low cost;
- low life cycle cost of the radar;
- competitiveness on the domestic and foreign markets.

The implementation of the requirements depends on the following factors:

- the progress made in developing multirole airborne radars, including active electronically-scanned antenna (AESA) ones;
- the use of publicly available standards that can be used in commonising the interaction of the hardware platform modules and all software environment components, which allows the implementation of open-ended systems;
- the use of digital techniques of probing signal conditioning and reception-path echo processing;
- programmability of airborne radar functional modules both at the manufacture stage and during their operation by means of control by the airborne digital computer;
- development of commonised baseline functional software.

Mention should be made that the tactical capabilities and effectiveness of warplanes and helicopters have been increasingly dependent on not only their flight performance and weapons, but also the functional capabilities of their weapons control systems based on multirole airborne radars. Along with tactical effectiveness, the effectiveness should also include the reliability and maintainability of control systems, which was been highlighted by the results produced by the Reliability and Maintainability 2000 Program (R&M 2000) in the United States. They offered a preview of the aircraft development, manufacture and maintenance cost ratio and the feasibility of optimising the systems' cost effectiveness.

In accordance with their purposes, airborne radars handle different classes of tasks and should have different tactical characteristics. Multirole radars perform air-to-air and air-to-surface tasks and should serve the basis for the development of airborne radar families.

The airborne radar families that could be developed in the near future to equip aircraft can be divided into three groups as follows:

- complex expensive multirole AESA radars;
- inexpensive compact multirole radars to fit unmanned aerial vehicles (UAV) and rotary-wing and fixed-wing aircraft;

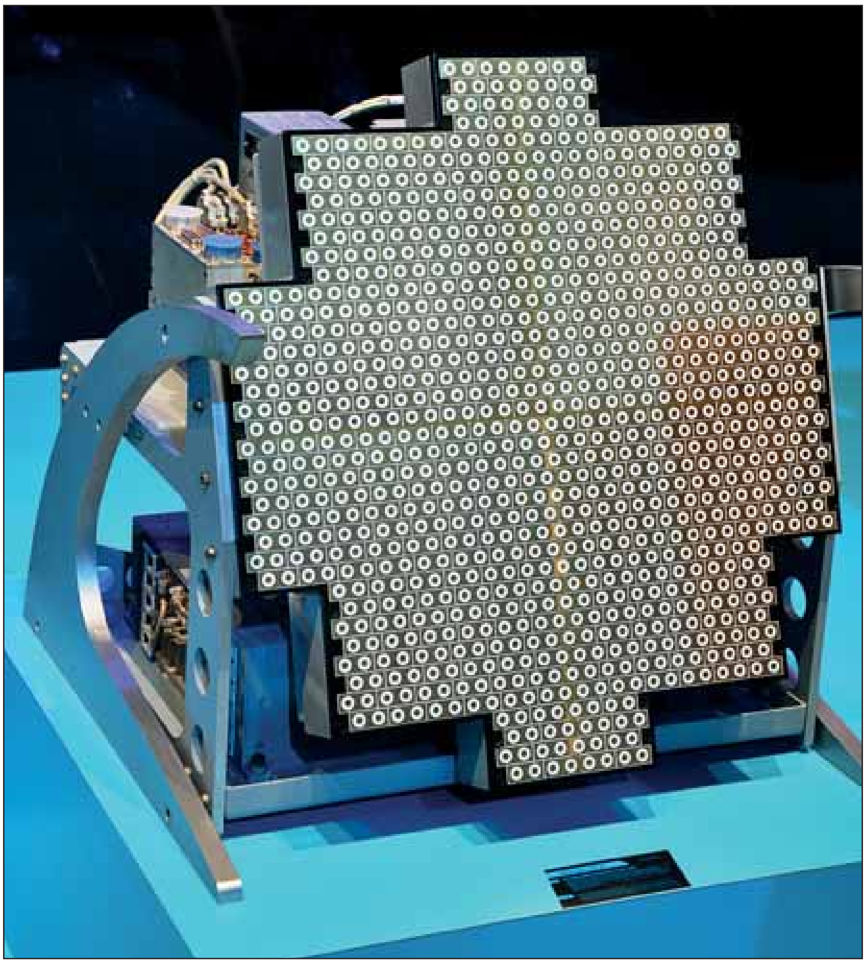


Fig. 1. A new-generation 3D-technology-based AESA radar

- miniature airborne radars to equip small-size UAVs.

The first of the airborne radar groups is based on the AESA that, as a rule, is the mainstay of the integrated radio-frequency system fulfilling not only radar tasks, but electronic intelligence (ELINT), electronic warfare (EW) and datalink tasks as well. The group is made up of extremely complex systems featuring a huge functional software package and a long expensive development cycle that is normally broken down into several phases. The phases result into the system's versions dubbed 'block' in the United States. The development of such systems takes decades. For instance, the radar of the F-22 aircraft had been in development from 1985 to 2005, with the latter date being when the delivery of initial operational capability (IOC) fighters to the US Air Force kicked off. At the same time, an announcement was made that a follow-on version with higher capabilities was in development.

The development of the F-35 aircraft's radar (radio-frequency system) is believed to have commenced in 1992. Its trials are under way.

Nominally, the upgrade of the F-15, F-16 and F-18 aircraft through replacement of their older-generation radars with AESA radars took less time. However, it was based on the progress made under the ATF programme dedicated to the F-22's development.

The second group is multirole radar systems featuring high cost effectiveness. They are designed for fitting UAVs, helicopters and light planes. Such radars rely on mechanically steered antenna arrays or, if necessary, arrays mechanically steered in azimuth and electronically in elevation.

The high effectiveness of such radars is owing to the digital methods of probing signal conditioning, reception path echo processing and subsequent processing by high-performance programmable airborne digital computers. The radars' life-cycle cost is reduced via a reduction in the number of electronic modules and the use of analogue and digital very-large-scale integrated circuits. At the same time, reliability increases considerably and, hence, the operating cost diminishes. The en-masse use of an airborne radar family on board UAVs, helicopters and light planes also offers an additional opportunity to slash the life-cycle costs of the radars in the family.

The third group is essentially a thing of the future, for the radars under development should feature sufficient functionality and their weight should be within 3–5 kg.

Implementation of airborne radar family design concept

Obviously, an airborne radar family should have common architecture, but the architecture's implementation in particular radar may be special. The specialisation like that is attained through the use of groups of standard devices, e.g. antennas, antenna modules, transmit/receive (TR) modules and transmitters. Specialisation through programming electronic devices (modules) is used widely, with the modules being programmed as part of production or in the course of operation while controlled by the airborne digital radar.

Mention should be made that airborne radar families may be developed on the basis of the hardware design and production technology commonality, which is the fact as far as AESA radars are concerned in the first place (Fig. 1). However, the principle is also applied to other airborne radars, e.g. those reliant on slotted-waveguide arrays. For instance, the Ka- and X-band small-size airborne radars (Fig. 2) being co-developed by Phazotron and MAI are part of a family of commonised airborne radars having the same architecture. They comprise commonised modules with standard interfaces and non-commonised ones, the latter being antenna arrays and microwave receivers they mount – all sharing the same technologies.

As international experience demonstrates, compact multirole radars are mostly designed for use as part of reconnaissance and recce/attack UAVs.

X-, Ku and Ka-band radars may serve a suitable compact multirole radar family as part of such UAVs. Fig. 3 should a baseline model of such a compact multirole radar family.

Different airborne radar families may also use such commonised mod-

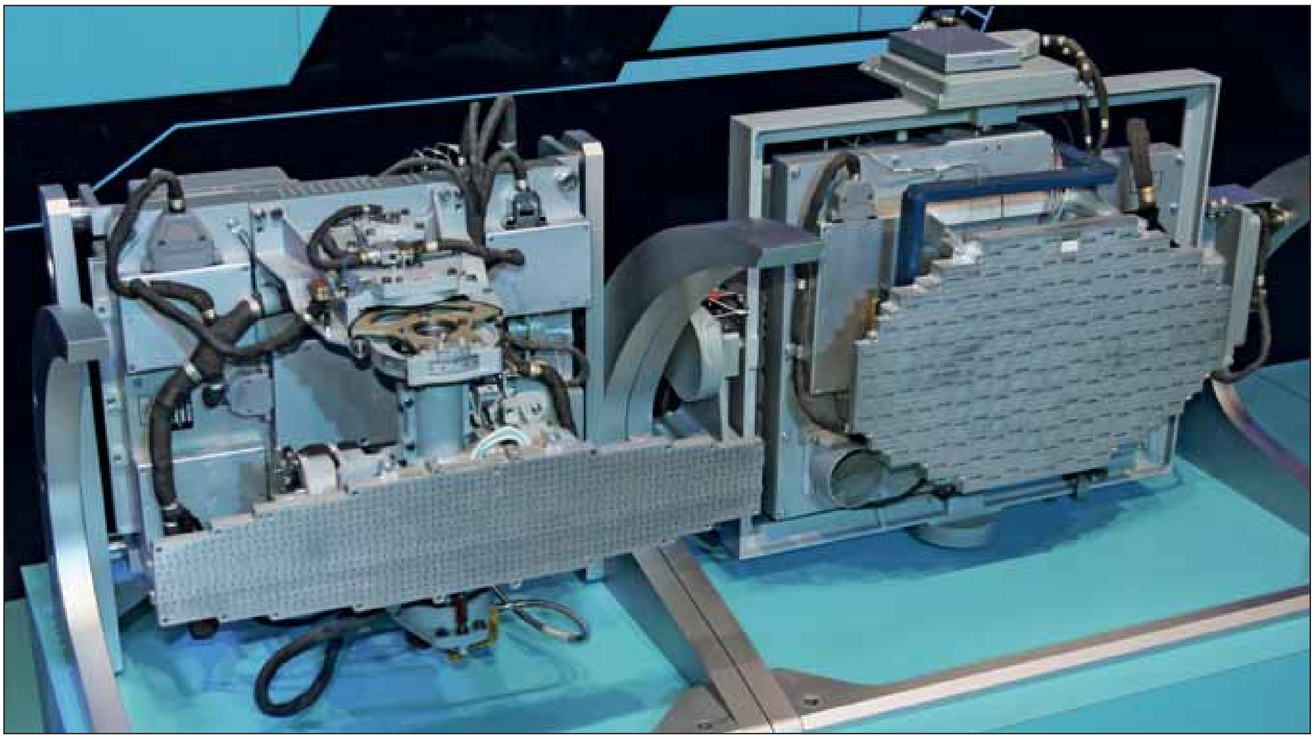


Fig. 2. Ka- and X-band compact multirole radars

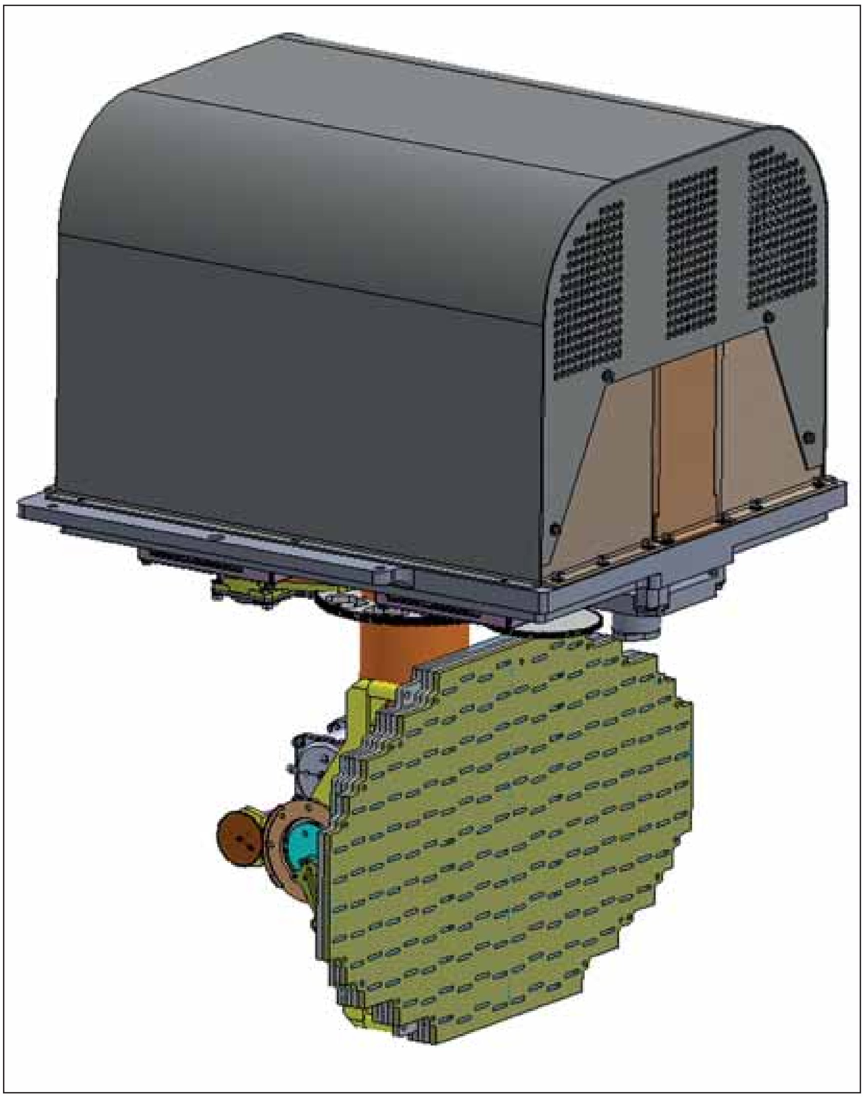


Fig. 3. Baseline model of a compact radar family

ules as airborne digital computers, digital receivers and digital frequency and clock signal synthesizers.

In development of airborne radar families, special attention should be paid to their software comprising system, functional and technology software. System software supplied together with the commonised airborne digital computer predetermines the commonality of functional software. It is important to commonise functional software's development technology and life cycle throughout the company as a whole. This is due to a large size and complexity of the functional software code. According to foreign sources, the size of the functional software code of the F-22's first variant is about two million lines, while the functional software of the F-35 accounts for six million lines of code in the C language.

The key components of efficient software design technology are up-to-date domestic and foreign software developmental and certification standards, their adoption by the company and the use of the closed-loop software development based on an electronic archive.

The suggested airborne radar family design concept will reduce the time and development/operating costs and hone the competitive edge of the corporation's airborne radars.

FORMAT.PRO computer-aided design system as design tool

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Programmers believe even a simple smoothly-operating program contains at least two errors. Complex software products, which development and editing takes several months or even years by different programmers, may have far more errors. Not the ones making a program unusable whatsoever; rather the ones causing situations that seem to be logically impossible or unpredictable in the course of programming, the situations the program normally never finds itself in. In case of malfunction or a sum of certain factors unforeseen by the programmer, however, there may be erroneous actions or a 'hang-up'. This would cause only irritation in office or at home, but this may result in an accident or an incident under the conditions critical as far as safety is concerned (plane, ship, nuclear reactor, wheeled vehicle).

To prevent such errors in complex hardware/software systems critical to safety, a computer-aided design system is developed. The CAD system allows uniting a class of tasks and developing a software code with the use of a code generator certificated prior to its use.

The article has been written owing to the release of a new version of the FORMAT.PRO CAD system.

The tasks in question are pooled into classes based on the same typical criteria exemplified by the following:

- Class 1 – tasks pertaining to generation of 'indicative images' (formats);
- Class 2 – tasks pertinent to control of objects (parameters of an object).

Today, the former class of CAD systems is exemplified by the FORMAT computer-aide design system used for generating 'indicative images' on the screen for the systems making up the aircraft's cockpit management system.

The FORMAT system is close to the SCADE DISPLAY package from French company ESTEREL TECHNOLOGIES in terms of functions, with the company being the trendsetter in this field.

The other class is exemplified abroad by the SCADE SUITE package from ESTEREL. Its Russian analogue is emerging in the form of FORMAT.PRO designed to automate the development and testing of applied software designed for control systems based on controllers, computer systems or electronic automata.

In addition to code generation, the FORMAT CAD system allows automated documentation of software under development, full-fledged testing,

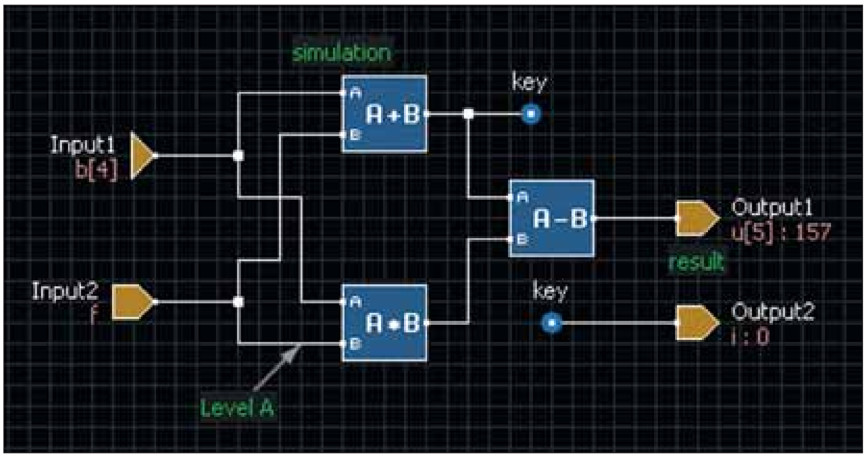

Fig. 1. An example of an image for control purpose

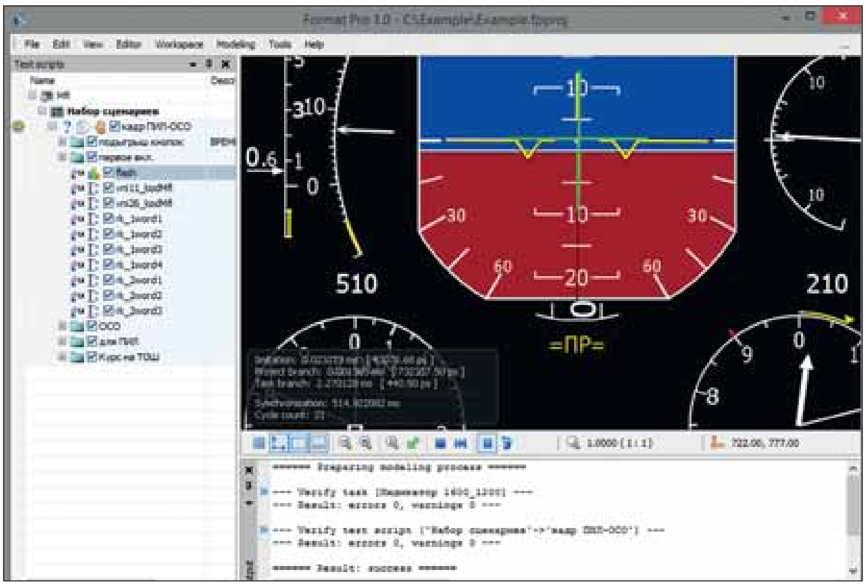

Fig. 2. An image in the test scenario mode

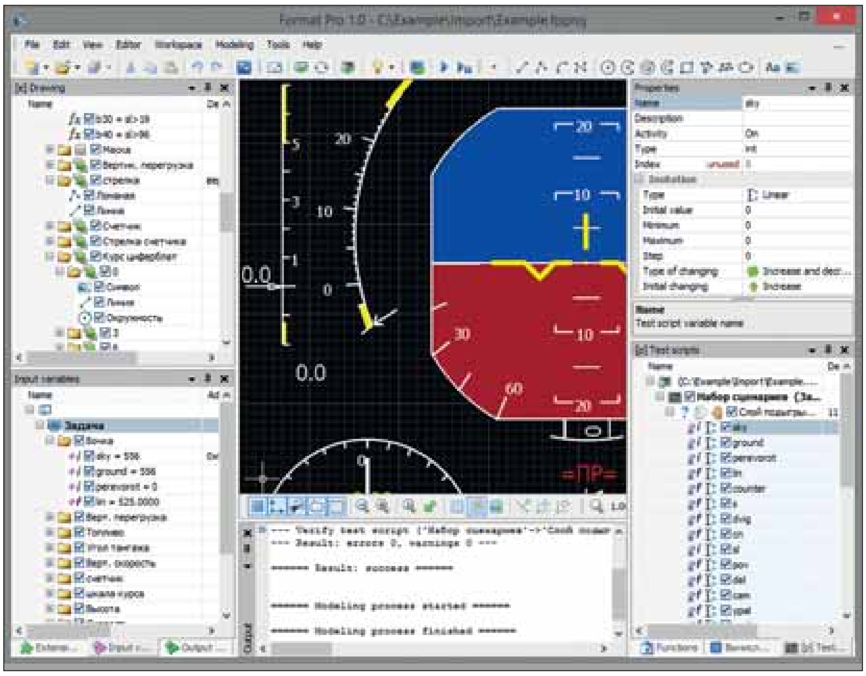

Fig. 3. An image in the modelling mode

Fig. 4. Workstation of a designer

debugging and a number of other important functions.

The effectiveness of the CAD system depends on its being dedicated to the performance of specific tasks in this sphere, rather than just mathematical modelling and display of its results. It is the set of service functions typical of the above classes that provides the edge on versatility.

As compared to the FORMAT, the FORMAT.PRO variant includes the second graphic editor ensuring the development of software for both displays/cockpit management systems and computers. Although not all of the ideas have been implemented to date, prospects should be given a thought right now. Integrated modular avionics software development with the use of the current and subsequent CAD versions will maximise effectiveness, reliability and program quality and slash the development time. How will this be done?

Instead of ‘paper’ protocols, algorithms will create other algorithms in the ‘second’ graphic editor of the CAD all by themselves. When presented in the usual form (Fig. 1), algorithms are easy to read, nesting level-scalable and computer-aided-tested; they are used for generating the code for computer aids. Today, the CAD system’s computing environment software generation capabilities are not huge, but they have provided a good beginning and the share of generated software will be maximised soon (as far as ESTEREL’s SCADE DISPLAY and SCADE SUITE are concerned, it stands at 80-95% of the software of the whole complex).*

Let us dwell on the field of use of the FORMAT.PRO CAD system as part of the integrated cycle of designing a plane, a helicopter, a ship, a submarine, etc.:

- at the draft design stage, the cockpit elements, algorithms and the appearance of the information displayed an be easily shown in the course of the design review;
- design of the cockpit layout and subsequent functional algorithm modelling on large liquid-crystal display (LCD) screens (maybe, touch screens) for the purpose of ergonomics research, as well as subsequent obtaining of medical opinion on whether information is displayed correctly or not;
- development of indicative formats and display equipment of the aircraft, and MFD/display software modelling and debugging;
- controller and computer software development and subsequent code generation;
- programs handling the display of information on real displays can be ‘cut out’ form the operational cockpit management system (its model on LCDs, to be more precise) and the MFD/monitor software can be produced by means of code generation (function of the CAD system);
- software improvement as part of the aircraft’s flight trials and subsequent operation;
- since the very first day of designing until several dozen years of operation, the CAD system’s ‘document generation’ function will allow having the current documentation that is not written by a programmer, but synthesised from the current software;

* There are always aircraft software elements that have to be written in Assembler or other languages for technological reasons.

Fig. 5. Control station of a ship

- the software developed for a particular aircraft can be used in the aircraft's simulator;

- classroom programme elements can be derived from the applied software.

Variants of the FORMAT and FORMAT.PRO CAD systems have been used for the development of the Su-35, T-50 and Su-34 warplanes and Ka-52 helicopter.

The development of the software of the MFD equipping the upgraded Ka-27 helicopter has been planned.

The FORMAT.PRO CAD system would ensure automation of the development of safety/security-critical applied software for avionics as well as systems used in transport, nuclear power generation, navy and other spheres.

The FORMAT.PRO CAD system is intended to become the baseline model in the above fields. This would allow an increase in the quality and reliability of equipment and ease modernisation and support against the backdrop of an overall drop in costs and a hefty reduction in lead time.

We hope for the FORMAT.PRO CAD system to become a design environment to designers and a versatile tool to chief designers all the way from the kick-off of a product's development until its disposal.

Hopefully, further development of the FORMAT.PRO CAD system will involve Russian research institutes and feedback from users. We believe domestic products are as good as Western ones and far more acceptable in many ways.

Fig. 6. Control station of a ship

Compact airborne radars – realities and prospects

Vladimir Kudashev, department chief, Phazotron-NIIR corporation
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Oleg Samarin, chief, research division, Phazotron-NIIR corporation

The Phazotron-NIIR corporation looked into the feasibility of the development of compact radars, featuring a wide range of air-to-surface and air-to-air modes, by means of a research effort that was completed in 2008. The effort was focused on researching in the feasibility of miniaturising compact radar key devices with the use of the electronic componentry available then. It also was used to work out the technical requirements and an approach to their implementation in future advanced radars.

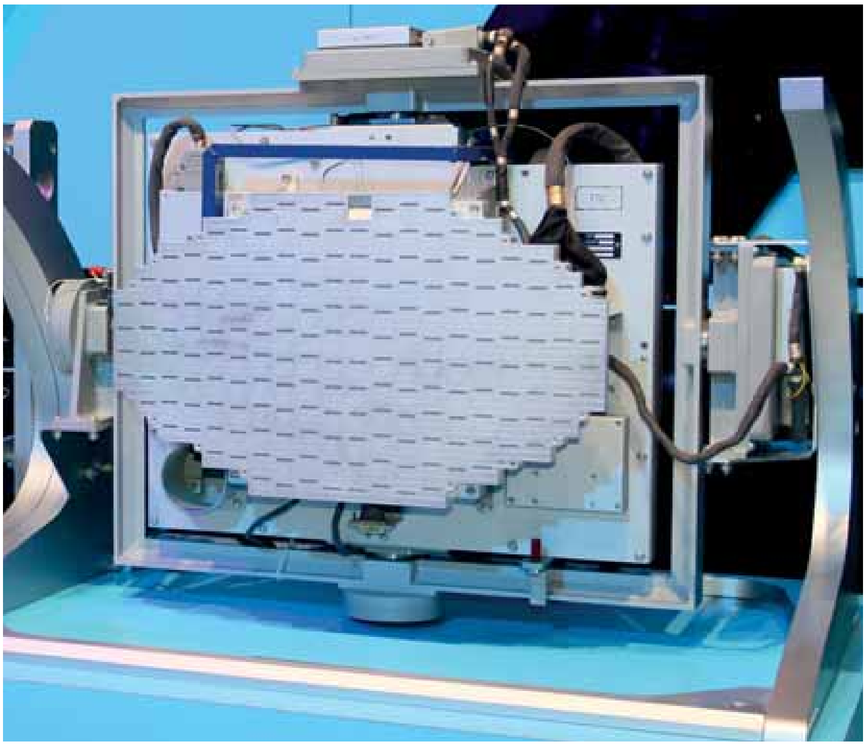
The Ku-band AN/APQ-8 Lynx was used as the prototype in the course of the compact radar concept definition but the Ka-band with a bandwidth of 640 MHz was chosen for the compact radar.

The research effort resulted in the following:

- compact radar design;
- principles of designing the functional software for multiprocessor high-performance computer systems using high-speed interfaces;
- algorithms and programs of the following operating modes:
  - low-altitude flight information support;
  - high-resolution imaging;
  - airspace surveillance;
- dynamic simulation models of outside environment;
- draft design documentation for a experimental example of the compact radar;
- experimental example test bench;
- draft performance specifications for the development of a future compact airborne radar.

Using the draft design documentation, the company developed an experimental example of the compact radar, comprising the following:

- antenna module (slotted-waveguide array), circulator, antenna/dummy switcher, loadings, microwave receiver, antenna drive mechanism and power supply);
- transmitting module (frequency synthesizer, TWT power amplifier and high-voltage power supply);
- synchronizer;
- digital receiver comprising two modules of analogue-to-digital converters;
- personal computer emulating the airborne digital computer and SRIO, MIL-STD-1553B, RGB, Ethernet, RS343A and RS232 interfaces;
- secondary power supply.


X-band compact multirole radar

Compact radar experiments involving the experimental example test bench mostly proved the compact radar design principles and technical requirements to the components and software to be correct. However, the following drawbacks, which were later corrected in the draft performance specifications for the development, were revealed too:

- low technical and operating characteristics of the TWT;
- limited set of the types of transmitting signals, particularly, the lack of intrapulse modulation;
- long frequency-tuning time preventing the implementation of the pulse-to-pulse frequency shifting;
- lack of the compensation channel by the slotted-waveguide antenna array and microwave receiver;
- insufficient degree of the digital receiver's integration;
- insufficient dynamics of the antenna drive and the imperfect design of the drive's electromechanical components;
- large and heavy electronic modules of the antenna assembly;
- shared secondary power supply module.

Realities

Another important phase of the development of a small-size airborne radar was the Phazotron and Moscow Aviation Institute (MAI) joint integrated high-technology production programme involving a

Russian higher education institution. The programme was dubbed Multirole Airborne Radar System High-Technology Production Facility Development.

Based on the performance specifications spelt out by the research effort, the developer devised the specification requirements to the Ka-/X-band multirole radar system prototype development effort. The requirements included advanced digital probing signal conditioning and digital echo signal processing methods and further integration of the functions within the hardware modules.

The following was completed as part of the above-mentioned development effort:

- detailed design documentation was prepared;
- functional software was developed;
- two multirole airborne radar prototypes were manufactured;
- preliminary tests were performed.

The multirole airborne radar, which development had been completed in 2012, not only meets the specification requirements, but also exceeds them considerably as far as basic parameters are concerned.

Patent for Invention has been secured for the original technical solutions used in the development of the multi-band scalable multirole airborne radar. Scalability is the feature of radar, characterising the latter's ability to alter its topology flexibly to meet the growing requirements as a system evolves, gets refined and is modernised. If a radar features a high degree of scalability, its complexity shows an insignificant increase, when new elements are introduced to it.

An in-flight experiment dedicated to testing the X-band channel of the multirole airborne radar and involving a light aircraft was held in January 2014. The experiment was aimed at testing the operability of the hardware and software and getting radar images at spotlight mode with a linear resolution of 0.5 m.

Since the plane lacked a navigation system, the testers decided to turn off the antenna control circuit, set fixed experiment conditions (air speed, altitude and flight path, imaging range and angle, probing signal parameters) and neutralise flight path instabilities with iterative non-parametric auto-focusing algorithms.

A total of 43 radio-frequency holograms with a coherent integration time of about 7 s each were recorded in flight, with the plane's motion rates (speed and

Fig. 1. A number of car service centres: (a) a radar image; (b) a photo

Fig. 2. A group of business and administrative facilities: (a) a radar image, (b) a photo.

altitude) deviating considerably – up to 40% – from the given ones. The testers selected four of the RF-holograms, featuring the quality desired and possessing sufficient information capability and zoom for the comparison of the flight area's radar images with its satellite photographs.

Following the relevant geometrical transformations (scaling, rotation, formatting) of the mapping area's photographs taken by a satellite, the photographs were superimposed on selected radar images. The superimposition proved the correct position of objects in the photos and their marks in the radar images for each area and enabled the testers to spot changes between the 2009 satellite photographic survey and the radar imaging. As exemplified by two areas, Fig. 1a and Fig. 2a show the radar images taken and Fig. 1b and Fig. 2B display the corresponding satellites photos.

The radiometric evaluation of the size of the marks of stand-alone pinpoint reflectors proved the radar images' linear resolution of 0.5 m in azimuth and range. At the same time, the radar images featured a high degree of both peak and integral side lobes, which degraded the information capability of the images. The basic causes of that are the signal's amplitude and phase distortions in the path and the lack of the antenna system control circuit and the navigational data on the carrier's motion.

Thus, the X-band channel multirole airborne radar in-flight experiment proved the operability of the hardware, software and design principles underlying the radar's development – high-resolution imaging modes in the first place. For the efforts to continue with success, the following is necessary:

- ensure that accurate enough navigational data are fed to the multirole airborne radar's computer and the antenna systems control circuit is operational;

- perform end-to-end calibration of the amplitude-frequency and phase-frequency characteristics of the transmitter/receiver path, including the transmission and receiving by the antenna, with the subsequent introduction of a corrective function to the signal processing software.

A considerable drawback of the two-band multirole airborne radar was the limited computing capabilities of the airborne digital computer. As is known, as far as airborne ground-survey radars are concerned, radar signal processing in high-resolution imaging mode is the most difficult computing task. It comprises a whole range of procedures known by engineers well enough and performed both in real time (while scanning) and in quasi-real time (once the whole body of samples for calculations has been accumulated).

At the same time, the use of probing signals with pulse-to pulse frequency shifting and intrapulse chirp modulation as well as rather stringent requirements to the accuracy of ground object positioning required an addition of new processing procedures:

- transformation of the frequency-shift sequence into a single wide-bandwidth RF-hologram;
- end-to-end (amplitude and phase) frequency response correction based on the transmitter/receiver path calibration results to reduce the side lobes;
- evaluation and compensation of the carrier's radial velocity measurement error with the use of the azimuth difference receiving channel;
- compensation of the radar imagery's longitudinal and lateral geometric errors caused by a scale and line-of-sight angle change and by the dependence of the signal's Doppler frequency on azimuth and distance.

The obvious complication of signal processing in the multirole airborne radar as compared with traditional algorithms has necessitated a considerable increase in the airborne computer's resources – speed in the first place. The development of its software package displayed that for this to be achieved, the computer had to have a total capability of at least 12–16 GFLOPS with the use of high-performance computing libraries and including losses. For example, the Elbrus-2C+ dual-core microprocessor has the capability required.

Based on the progress made by the afore-said research efforts and subsequent development efforts, MAI and Phazotron-NIIR are running a joint programme on the development of a UAV multirole radar payload. Unlike the previous multirole airborne radar relying on an airborne digital computer from the Integrated Research Institute of the Russian Academy of Sciences, the new UAV multirole radar payload included a high-performance computer system comprising a processor module and a digital receiver. The processor module is based on the Elbrus-2C+ and interacts with the four-channel digital receiver via a PCI-Express bus. The solution allowed a hefty increase in performance and a marked improvement in the weight and dimensions of the digital processing system.

Prospects

Numerous discussions at arms shows, especially MAKS 2013, and working conferences have displayed high demand for small-size multirole airborne radars intended for panoply of commercial and military platforms – fixed-wing and rotary-wing aircraft and multirole UAVs.

In particular, weather radars with various capabilities are needed for plane and helicopter flight safety. For instance, airliners require multirole airborne radars capable of assessing weather, warning the crew to avoid aircraft and terrain collision, scanning the ground and conducting 3D signal processing that provides the crew with in-flight information support under adverse weather conditions by generating imagery as cross-sections of the three-dimensional representations of weather phenomena.

The echoes received by the airborne radar are known to be able to carry information on both weather phenomena and the underlying terrain (water or ground) at the same time. Extracting only weather data or only surface ones from the mix is no small beer. The problem is resolved in the most effective manner if the data are divided into components based on a map of relief. The following is required as part of the processing:

(a) getting accurate enough radar-assisted positioning of objects through the use of monopulse direction-finding, probing signal duration extension, etc.;

(b) superimposing the radar's system of moving axes and the fixed digital ground map stored in the airborne computer;

(c) breaking the radar data down into components with the use of the ground map's height matrix as a filter;

(d) having correct accumulation within the 3D database of weather phenomena and surface data reflected throughout the scan zone;

(e) generating and displaying (by turns or simultaneously) a weather map and radar imagery of the surface by means of processing 3D database information.

Mind you, the multirole airborne radar performs similar 3D data processing in low-altitude flight information support mode.

Advanced passenger and cargo/passenger helicopters also require weather radars, albeit having a reduced functionality, which are especially useful under adverse weather conditions typical for Russia's northern areas.

A special market segment is made up by search-and-rescue (SAR) helicopters and planes needing multirole radars able to spot moving people, gauge the coordinates of aircraft, ships or ground vehicles in distress and assessing the aftermath of catastrophes. The aforesaid means of transport or their fragments have to be found under foliage or grass, in soil, marsh or under water. Multirole multi-band airborne radars are required for this purpose.

Similar tasks are handled by the radars of patrol planes and helicopters over water areas and in adjacent areas.

The above tasks predetermine the development of a data processing system featuring very high computing capabilities – speed and storage capacity. A prototype of the system like that could be served by the airborne computer system of the core of the integrated modular avionics, particularly, the digital data processing airborne computer system. The airborne computer system's digital signal processing module is based on the quad-core TMS320C6674 microprocessor with the 64 GFLOPS peak performance.

The domestic analogue of the microprocessor may well be the Elbrus-4C quad-core microprocessor – a derivative of the Elbrus-2C+ being used as part of the processor of the airborne digital computer under development to fit the UAV multirole radar payload.

Another rather pressing problem of future multirole airborne radars, especially multiband ones, is a hardware platform weight and size reduction. A solution is to develop a multirole airborne radar family and seek for special variants of mounting airborne radars on specific carriers.

This will necessitate a range of research into development, selection and introduction of cutting-edge technologies ensuring a considerable weight and size reduction.

Airborne pulse Doppler radar's hovering helicopter acquisition mode

Arkady Forshter, departmental chief, Phazotron-NIIR JSC

The hovering helicopter acquisition problem has dated back several decades. To date, it has been resolved as far as ground-based radars are concerned, but there is no information about the implementation of the operating mode in airborne radars either abroad or in Russia, not in the public media at the least. Presumably, this is due to peculiar technical problems that are not encountered by ground-based radars.

The thing is that airborne pulse Doppler radars equipping fighter jets perform target acquisition in lookdown mode, which leads to corresponding limitations, with the nature of those to be discussed below.

Let us start with the peculiarities of probing signal returns reflected by a hovering helicopter.

The reception path of the airborne pulse Doppler radar has the so-called echo spectral component notch area, with the spectral components corresponding to the echoes bouncing back from the surface. In Fig. 1, the area is shaded. Its beginning is marked as F_{mbpatt}, i.e. echo periodicity along the main beam of the antenna pattern.

F_{vdop} is the Doppler frequency corresponding to the plane's own velocity.

Surface echoes are received not only via the main beam of the antenna pattern, but via the sidelobes as well. F_{cf} is the cut-off frequency of the notch area; it can equal or exceed the F_{vdop} value.

Since the Doppler frequency of the echo reflected by the airframe coincides with F_{mbpatt} (hovering helicopter), one can count only on the echo reflected by the blades of its rotating main rotor. The Mi-8 helicopter's main rotor has five 10-m-long metal blades. Therefore, the pattern of the back radiation of a blade in azimuth has a width of about several fractions of a degree. Hence, given the 3-4Hz main rotor speed, the duration of the packet of the signal reflected by the rotating blade will stand at 200–300 µs, i.e. the signal is a burst. Therefore, the width of the echo's bandwidth equals 3-5Hz. In Fig. 1, the signal envelope is shown as a hashed red line. The closer the F_{cf} to F_{mbpatt}, the greater part of the echo's bandwidth is within the acquisition area and the greater the energy used for its acquisition, but the energy may be insufficient at certain values of the F_{cf} - F_{mbpatt} difference.

The brief burst necessitates the use of high repetition rate signals. For such pulses to be enough during the burst, their repetition rate should be about 100kHz.

Since there is no accurate information about the shape of the burst as far as different helicopters and different main rotor configurations are concerned, the author decided against the incoming signal's coordinated processing, which led to the devising of a procedure retaining its operability despite the parameters varying highly enough. The procedure was worked out using the median Minimum Bayes Risk criterion.

Since the bandwidth is continuous, rather than linear and its parameters are hazy enough, the probing signal modulation techniques currently in use for target ranging turned out to be inapplicable. A decision was taken not to range the target while scanning, all the more so that the dwell time is about

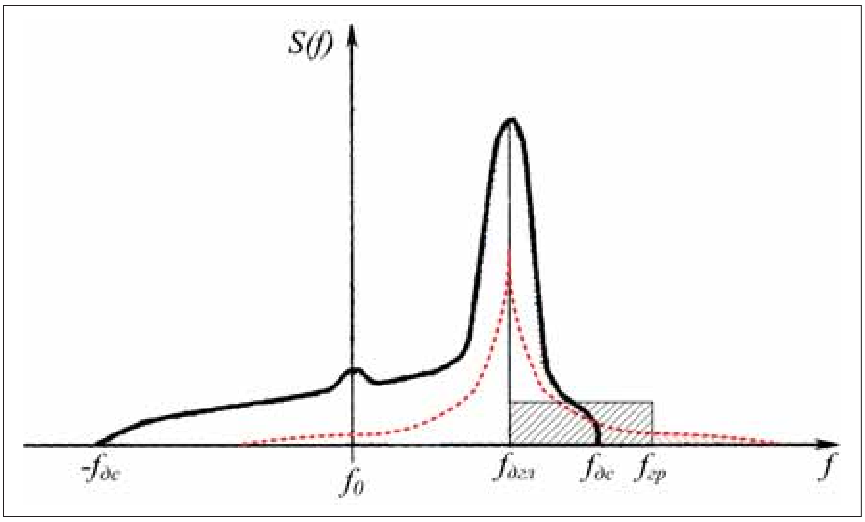


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

60 μs when a relevant area is scanned. Since the Mi-8's radar return burst period equals 50-60 μs, the target has to be acquired using a single burst, while the burst's position within the observation interval is unknown, which has complicated the target acquisition procedure by far.

Another complicated problem was the hovering helicopter lock-on ranging. In the course of acquisition of an ordinary target after the scan mode, in which range is gauged, as a rule, there is preliminary target designation, albeit not very accurate, which simplifies the ranging procedure during the lock-on considerably. Nevertheless, the painstaking development has resulted in relevant algorithms. Flight trials have proven the effectiveness of the solutions embodied in them.

Fig. 2 shows the screen of the multifunction display (MFD), with a hovering helicopter detected out to approx. 27 km. The characteristic 'helicopter' mark is visible. Fig. 3 shows the moment when the radar locked on the target. The pilot placed the box onto the target mark, the target was ranged and the lock-on took place. The target range is 25 km. The above-mentioned target acquisition range, 27 km, was calculated by means of backward extrapolation using the range gauged during the lock-on.

During the flight tests, the helicopter was at an altitude of 200–400 m, with the fighter flying at 2,200–2,400 m.

Fig. 4 shows the MFD screen in the course of tracking the hovering helicopter. The tracking had lasted until the elevation angle reached its maximum.

In Fig. 5, the range change during the tracking of the hovering helicopter based on the data provided by the recorder is depicted in red. The blue colour indicates the antenna's scanning of the scan area in azimuth and the green colour shows that in elevation.

The echo reflected by the helicopter's tail rotor emerges at a distance of 12–13 km, with its repletion rate being about 20 μs. The range tracking algorithm uses both signals, with the tail rotor's 15 m shift relative to the main rotor having no impact on the quality of tracking.

In conclusion, the author is stating that the flight trials have fully proven the hovering helicopter acquisition concept devised, albeit with some reservations, which will allow the mode to be refined in the future.

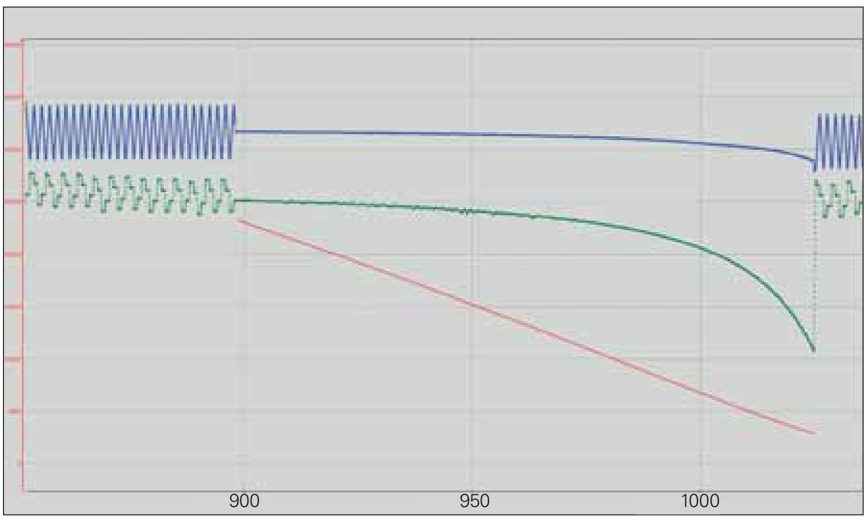


Fig. 5.

On essence of precision-guided weapons

Bogdan Kazaryan, professor, Academy of Military Sciences

The evolution of armament, force structure, firing techniques and operational art are process influences one another mutually. The purpose, tasks and application methods of combat gear are based on their properties and characteristics. The capabilities, tactics and forms of using military forces are based on the capabilities of their weapons, organisation, manning, skills, cohesion, experience, morale, control level and support.

The properties and sophistication of combat gear and military organisation show in the sets of tasks and operating algorithms of headquarters. Their effectiveness, in turn, depends on the knowledge, language and culture of both commanders and combat gear designers.

The linguistic factor of ensuring the unambiguous conveying and perception of the meaning in command and control (C^2) and armament development and application should be paid appropriate attention. Errors in documents and opinion lead to errors in the operation of combat gear and complicate the relations among people.

The causes of the incomplete linguistic identity in combat gear development and use are incomplete professionalism in one's main and closely-related spheres and the use of surrogates of the technical, computer, legal and economic languages. These are contributed to by insufficient education in literature and language, lower standards in the media, bureaucratese, and the Internet-induced acceptability of writing without actually thinking, without being bothered by the rules.

To teach the use of the Kalashnikov assault rifle, the 'do as I do' approach, a poster and the range practice manual are enough. As far as automatic and automated systems are concerned, one needs the publication, knowledge and ability to use numerous documents on their operation. Methods of using automated decision-making, planning and command/signal systems, databanks and databases later the routine of headquarters and command post personnel, all the more so in the course of tasking, preparations and accomplishment supervision.

The basis of various instructions are devised by designers who describe the tasks, methods, operating algorithms and responsibilities of operators. Along with operational-tactical notions, special terms – technical slang stemming from the hardware development, poorly related to military terms and inadmissible for use – are introduced to documents.

Take, for example, the term 'target designation'. By intuition, civilians encountering it believe that an intelligence, surveillance and reconnaissance (ISR) asset 'sees' a target. Actually, the equipment records signals, e.g. amplitude, frequency, phase and time values. Their tactical information capability shows, if such information is provided to skilled operators able to understand and use the resultant diagrams, tables and symbols.

The terminological ambiguity started increasing with the emergence of the term 'precision-guided weapons'. Now, it is hard to pinpoint the sources, which technical translation's error introduced the phrase into Russian. There also cropped up such expressions as 'air-based (sea-based, ground-based) weapons', 'non-contact action', 'new physical principles', etc.

Ships, launchers and planes are armed and fitted with precision-guided weapons, according to their operation manuals. According to military manuals, aviation, naval and support command units are based, i.e. placed in an area (on the ground, but not in the air or at sea). In the course of their operations, they use the systems of interconnected bases, airfields and other installations and organised ground. When non-contact action is mentioned, it meant that a belligerent has got no up-to-date weapons, for a real enemy, possessing effective military capabilities, will not permit any 'non-contact action' to be applied to him. 'New physical principles', including 'kinetic', are just illiteracy. You'd think somebody has appointed the kinetic energy of the catapult, dating back to the beginning of the Christian era, a 'physical principle'.

Universal laws, which are definitions, have been called physical principles from time immemorial, e.g. Newton's second law is the definition of force, energy conservation law, quantum mechanics principles, etc. The fundamentals of a theory are principles too. Emissions and energy used in weapons are the material world's objects and manifestations that cannot be attributed to 'physical principles' absolutely.

The phrase 'missile flight assignment' has been used for the flight programme (flight schedule) and the data especially prepared for navigation, search, acquisition, identification and aiming at the target. A pilot or a scout – a human being – gets an assignment, while a unit gets a mission.

Formation and disposition are an arrangement of Army, Navy or Air Force units, which is corresponding to the concept of operation, while designers mean by that "the positional relationship of missiles or other weapons in space", which, actually, is the 'formation' – mutual positioning in the air for group flight and concerted fighting. Missiles do not fight; their control systems merely fulfil re-formation programs.

New terms are introduced into the military without proper verification for compliance with the language rules and scientific-technical and tactical terminology. The low use of new military-technical terms by the troops prevents the latter from grasping their meaning, correct them and attain their common understanding. Language work as part of research and development is not funded. By default, it is believed that unlike mathematics, the basic language skills acquired in high school are enough. Manual-drafting and other committees of the Defence Ministry, as well as linguistic institutes, are not involved in this kind of work. Cultivating high literacy in engineers along with teaching them the C++, Java and other programming languages remains just a dream. Unfortunately, the Babylon syndrome manifests itself at scientific and technical council sessions as well.

The discrepancy between the terms used and the contents intended takes place at the juncture of scientific and technical spheres, on the one hand, and all things military, on the other, thus disorganising information cooperation and C2. This is a cause of the protracted transformation of the programmes and methodologies of using quite advanced combat gear into operating algorithms of headquarters and staff officers.

There is a need for a sophisticated military-technical thesaurus similar, say, to the JP1-02 DoD Dictionary of Military and Associated Terms or glossaries and lists of acronyms and definitions (NATO's AAP-6 and AAP-15) intended for use in documents and publications.

Combat gear designers need to learn military terms and command and control theory and practice, and combat gear users and designers need to hone their professionalism, knowledge, skills, abilities and behavioural patterns to the top level of production, societal and spiritual relations.

The perfection of the language formalisation and object description rules as well as accurate military-technical and operational-tactical definitions and terms are the preconditions for efficient information processing, continuous correct representation of the fluid situation, and integration of precision-guided weapons with automated control, ISR, strike and other systems.

Precision-guided weapons. What has been introduced?

The term information capability and accuracy problem was accentuated when a new systemic phenomenon – precision-guided weapons – was introduced into the present-day weapons system.

The definition 'Precision-guided weapons are guided weapons capable of eliminating the target with the first shot with a probability exceeding 0.5 within their range' was first included into the Military Encyclopaedic Dictionary in 1986. By the 21st century, the games of words, figures and wishes had driven the kill probability al the way up to 1. However, this has not been proven by experiment or by action.

It is yet impossible to get absolutely accurate aiming and guidance data for 'precision-guided' systems. Therefore, there has been no optimal balance among the accuracy, information capability and currency of the data for reliable guidance, on the one hand, and the effects and other characteristics of missiles, on the other. Otherwise, the staged engagement law (acquire, launch and leave) would be used in the calculations for the use of precision-guided weapons.

A number of precision-guided weapons definitions emphasise the kill as an integrated indicator. The requirement for attaining it is precise guidance – the only argument of the whole of the current sum of factors of weapon employment, target state and countermeasures. There are definitions mentioning the reliability of hitting the point required, but keeping mum about the kill of the target.

As any other weapons, precision-guided ones are not universal in terms of either targets or conditions of engagement. However, all definitions of PGW lack the mention of the diversity of the types of targets and the states they can be in, with the kill probability for the targets having to be about 1.

The appearance of rigorousness of all precision-guided weapon definitions is ensured by the significant figure of the kill probability. An effectiveness expert would say that the reasoning and calculation of the hit or kill probability is not performed as far as a single munition is concerned. Actually, the current definitions are very amorphous. They mention the only parameter – a high probability of the accurate delivery of the munition to the target. The parameter is impossible to use, because there is no mention of the conditions, under which the kill should take place (type, size, state and position of the target; parameters of the warhead's effects on the given types of objects; countermeasures and interference factors). Therefore, weapons using target designation, and weapons using target (or reference point) aiming are attributed to PGW. Artillery, small arms and even commandos fall within the definitions like that.

What is the difference among them?

Weapon reliant on target designation – precision-guided weapons – use data for being guided to objects outside the range of the carrier's own surveillance equipment. Targets are detected by designated personnel at the command post with the use of al materials available. The aggregate account of various data allows prevention of errors exceeding the obtainable accuracy of missile guidance, while taking account of possible approaches to the target, attack techniques and the characteristics of the target.

The missile's avionics package exercises its self-contained positioning relative to the given points in terms of coordinates, position, direction and time. Control signals allow keeping the positioning and guidance error within the permissible limits, considering which the warhead's properties were optimised. The guidance error does not depend on range, time, flight and guidance conditions, and peculiarities of the flight path and manoeuvring in the vicinity of the target.

In the weapons, which use aiming for shooting or launching, account is taken of the mutual position of the weapon, target and reference points as well as ballistic and weather data. As far as the target is concerned, only information on its protection is needed. Aiming errors and incomplete knowledge and consideration of the situational parameters lead to an increase in linear deviation, as the range to the target increases.

The phrase 'accurate aiming weapon' is controversial in several respects. Firstly, it substitutes the notion 'accuracy of fire'. Secondly, its meaning as an integral characteristic of the 'weapon – conditions – information – target – crew skills' system is not clear. Thirdly, aiming is reduced to the manipulation of combining the crosshairs and the target (reference point). Generally, if something is not accurate, it is neither weapon, nor tool.

The actual experience of using nuclear and precision-guided weapons in combat has been gained by the UN military only. However, the organisational, operational-tactical and system engineering aspects of the operation of their systems and the latter's role in engagement of the enemy are generally clear.

Firstly, the precision-guided weapons system emerges, if there is a sum of mutually related hardware-software complexes for self-contained control of munitions (navigation and guidance), ISR, information gathering, special data preparation and C^2 and weapon control automation. The complexes operate consecutively and simultaneously. The technologies used are compatible, the requirements to guidance information are consistent.

Secondly, for the components of precision-guided weapons to function, there is the need of diverse data (special maps, imagery, diagrams, coordinates), which complete information capability is created through their systemic development and employment. Some of the data are fed to command posts for strike planning. Other are entered to PGW's onboard self-contained guidance and navigation packages after launch or firing and are used for target identification. As a rule, it is not visualised by man. The data are devised by means of special hardware-software assets using available raw diverse data gathered via direct observation (filming) and analysis.

Thirdly, to use PGW, target selection, evaluation, distribution and designation, interaction and support functions should be redistributed from the tactical level to the operational one. Methods and algorithms of planning and preparing target designation data similar enough to those used by staffs as part of control and data processing systems.

Hence, precision-guided munitions (missiles, artillery projectiles, smart bombs) cannot be regarded as weapons unless they are considered together with the organisational and technical system of C^2, ISR and information and other support. They can be serviced, given a stencilled slogan, brought to the launch point, but they cannot be employed outside of the PGW system. All PGW definitions lack the mention and assessment of the importance of these aspects of PGW.

Numerous attempts at researching into the properties of the PGW system offer an idea that has long been entertained by scientists. Most of PGW's properties are considered by example of one kind (type) of assets with the control and data loop implemented in the form of the homing head. At the same time, the suggestion that actual countermeasures for PGW should be taken into account as part of the assessment of PGW's effectiveness proves that the current definitions are as relative as they are wrong. A reduction in accuracy or the loss of the lock on the target for this reason degrade the actual efficacy of attacks compared to the accuracy displayed at a missile range, i.e. munitions attributed to PGW prove to be very inaccurate and ineffective.

Thus, let us dwell on the essence of PGW again. PGW are the ones capable of self-contained control ensuring required guidance accuracy and effectiveness against strictly defined kinds and types of targets a particular situation with the use of specially prepared data. This also means that PGW employment should be assessed using the methods of the combat effectiveness theory. Another thing setting PGW apart from other munitions is that the accuracy of bringing a missile to a specified point depends on the information properties of the target's images.

The self-contained operating capability and high performance of PGW's systems emerge through the joint employment of ISR, information support, target designation and aiming and flight preparation systems as well as missiles per se. Their operation is interrelated. Elimination of any of these components from the system precludes the emergence of the system. The latter's effectiveness depends on the quality of mission accomplishment at all stages, such as planning, target distribution, designation, flight data and aiming cues computation, flight programme generation and fulfilment, and damage assessment.

Automatic equipment does not extend the coverage and engagement range, munition lethality, guidance accuracy and damage level. Real-time intensive continuous data exchange with automatic equipment is established. Data are used in a more efficient manner, computation algorithms become quicker and more accurate, and solutions become more rational.

Automatic equipment enhances the self-contained operation capability of PGW in the course of searching for, identifying and locking on the target and homing in on it outside the scan zones of relevant onboard and ground-based equipment. For this purpose, lists of thoroughly harmonised functions, options, parameters of systems and effects of the weapons are extended. With the advent of PGW, target distribution, target designation and damage assessment are handed off from the tactical level to the operational-tactical one. At the same time, the C^2 and weapons control functions are retained, with their centralisation and validity increasing.

As far as PGW are concerned, many experts guided by the current PGW definitions and understanding (e.g. 'launch and leave' slogan) believe the damage assessment problem is farfetched. Therefore, the 'net-centric theory' does not provide for damage assessment as a function of 'control and sensor array'. Still, damage assessment is a sine qua non for PGW control processes.

A problem posed by the role of the operator within the PGW system has surfaced. The responsibility and right to identify what is detected (objectives, activities of the forces, enemy intent) and take a decision are vested in commanders and operators reliant automatic equipment. If a high-value target is developed, target designation and missile launch are approved. If targets are of lesser value, they are planned for elimination as part of future strikes. If enemy action – a manoeuvre or intent – is developed, other decisions are taken. The procedures are executed continuously in response to every target or situation report. Thus, the sum of the procedures and options of automation has considerably increased human responsibility for the PGW employment purposefulness.

The organisation of PGW systems and their introduction into the armament system is done through the dialogue of professionals – designers and the military. Their ability to share the understanding of the processes pertinent to the preparation and employment of PGW and to understand one another entitles and enables them to jointly describe functions, technologies and anticipated results, develop algorithms and select regulators. The dialogue and the devising of documents continue in the form of experiments and tests aimed at making hardware, software and methods accurate, reliable and fit for operation in the most complicated situation.

The current stage is complicated by the problem of the unity and information capability of the professional language. A solution is a specialised expert examination of documents devised in the course of development work. This also would allow an improvement in language training and a purposeful influence on the thinking and culture of designers, engineers and commander.

The language used by scientific and technical specialists will become efficient, if it becomes part and parcel of the national language and culture. There are good examples to follow – classic literature and books on mathematics, physics, chemistry, etc., containing systems of axioms and rules, and complexes of mathematically interrelated physical constants, measuring units and definitions.

MiG Aircraft – World-Level Brand

Yuri Polushkin, chief designer, Mikoyan Design Bureau Engineering Center
Lev Shengelaya, chief designer, Mikoyan Design Bureau Engineering Center
Leonid Scheftel, deputy chief designer, Mikoyan Design Bureau Engineering Center

This is a yet another publication dedicated to the history of the development of legendary MiG aircraft.

It so happened that outstanding designer and a remarkable personality Rostislav Belyakov passed away on the last day of February 2014 – just three days short of his 95th birthday. He was involved as the principal action party in the development of all aircraft mentioned in our publications – from the piston-engined MiG-3 to the latest-generation fighters – more than 200 designs and 120 flying types, with the most prominent ones being the MiG-31 and the MiG-29 family.

Regrettably, a number of known circumstances prevented him from implementing one more significant plan for a new-generation multirole fighter called by him as an "anti-whatever". In terms of flight performance and combat effectiveness, the aircraft was supposed to surpass the fighters currently referred to as the fifth-generation aircraft. The idea essentially involved the future development of a light or even super-light fifth-generation fighter.

MiG-31

The development by the USSR of the MiG-25P high-altitude interceptor and S-200 long-range surface-to-air missile (SAM) system resulted in a modification to the US bomber fleet tactics: the USAF bombers switched to long flights at low altitude or even at very low altitude in VFR conditions in daytime. Such flights increased crew fatigue and reduced service life, but significantly increased the chances for mission success. If targets are destroyed using fighter-bombers, which number may exceed that of bombers, the density of raids will increase.

These factors, coupled with the development of low-altitude terrain-following stealth cruise missiles, caused additional requirements to the interceptor, e.g. interception of stealthy targets at long distance from the base airfield and multi-channel target engagement.

Another new requirement was to use interceptor packages with the enhanced capability of intercepting high-altitude high-speed targets.

The original plans called for upgrade of the MiG-25 by installing advanced radar, sophisticated missiles and an up-to-date engine (D-30F6), with the engine optimisation viewed as the main challenge. In this connection, G.Ye. Lozino-Lozinsky was appointed chief designer of the aircraft, as he had worked as deputy chief designer for powerplants. The position of chief designer was subsequently assumed by K.K. Vasilchenko, A.A. Belosvet, E.K. Kostrubsky, A.B. Anosovich and B.S. Losev.

However, quite shortly, the only element retained from the MiG-25 was essentially the aerodynamic configuration. Actually, a new aircraft was developed, featuring a new fuselage, new engines, airborne radar, avionics, a new two-seat

MiG-31 interceptor

MiG-29SMT fighter

cockpit, belly-mounted missile stations, main landing gear of original design, reinforced air intakes and a larger fuel load. Ground spoilers were dual-hatted as landing gear doors.

The same goes for the wing that included leading-edge root extensions (LERX), new airfoils, high-lift devices at the leading edge, and reinforced structure to withstand higher IAS.

The feature of the new warplane was an airborne phased-array radar (PAR) and long-range air-to-air missiles. The PAR on a fighter was a pioneer approach. In addition to a longer detection range, application of the PAR allowed the multiple-target detection and engagement capability. The aircraft also was fitted with the GSh-6-23 six-barrel rapid-fire gun as an auxiliary weapon.

The new aircraft was designated as MiG-31.

In parallel with the development of the interceptor, work was in progress on developing an attack aircraft and a reconnaissance aircraft.

The first two MiG-31 prototypes used the wing of the MiG-25.

The maiden flight of the MiG-31 prototype was made on 16 September 1975 by test pilot A.V. Fedotov.

Later on, the early prototypes were brought to the configuration of the standard prototype, with several aircraft built by the manufacturer plant. By late 1978, Phase A of the state trials had been complete, and the next year, the aircraft entered mass production. With the trials completed in 1980, the aircraft entered service in 1981.

Production versions of MiG-31

The MiG-31DZ is the air-refuellable version with an improved navigation suite to ensure rendezvous with tankers and ensure flights in high latitudes all the way to the North Pole.

The MiG-31B was fitted with then upgraded Zaslon-A airborne radar, upgraded air-to-air missiles, additional weapons on under-wing hardpoints – two R-40T (TD) missiles or four R-60 (R-60M) missiles, the mid-air refueling system and improved navigation and communication suites to enhance the group operation capability.

The MiG-31BS is an overhauled variant of the prior aircraft to a standard close to the MiG-31B.

The MiG-31BM is the version with the upgraded airborne radar and avionics (modern computers, display systems and extended target acquisition range).

Prototype aircraft

The MiG-31M is the version with an improved airborne radar, the Zaslon-M, advanced long-range missiles (up to six instead of the four carried by the previous version) and RVV-AE medium-range missiles. The navigation suite uses updates from the satellite navigation system. The aircraft is powered by modernised D-30F-6M engines and has an improved ergonomic cockpit, a larger fuel capacity, an air refueling capability and improved self-defence aids. The main efforts focused on the development and production of the MiG-31M pilot batch. Although the trials proved that the aircraft met the tougher requirements, the programme was suspended.

The MiG-31E is the export version of the aircraft. A demonstrator was made to show the capabilities of its weapons load against land-based and airborne targets.

A few aircraft were converted to look into the feasibility of using a number of sophisticated systems, in which development the Mikoyan Design Bureau was not the leading organisation.

MiG-31s were extensively engaged in flight experiments to identify the utmost interception capability and application of the advanced targeting and control systems.

Multiple design solutions were analysed, including, in particular, taking a capsule with passengers to very high (transatmospheric) altitude, and many engineering studies were performed to improve performance.

With over 400 aircraft manufactured at the facility in Nizhny Novgorod, even today

MiG-29K carrier-borne fighter

MiG-31 has every reason to be viewed as the world's best interceptor, guarding the borders of our Motherland.

The MiG-31 was not exported. Some time after disintegration of the USSR, several aircraft were remained in Kazakhstan.

MiG-29 family

The Mikoyan Design Bureau viewed the development of light tactical fighters as a most important task and, therefore, would start working on a new light fighter even before the full-rate production of the preceding model was terminated. That was the case when the decision was made to design a replacement for the MiG-23. The replacement was designated MiG-29.

The aircraft was designed with the focus on the Air Force requirements and with the MiG-23's operating experience taken into account. The aircraft characteristics also were required to surpass those of US fourth-generation fighter F-16 developed not long before. Given the Soviet experience in the development of the Su-25 and then-latest versions of the MiG-27 and Su-17 and the experience in the tactical use of the MiG-23, a decision was made that the new design, unlike the F-16, should primarily emphasise the fighting performance, namely:

- a better thrust-to-weight ratio and manoeuvrability;

- a combination of a powerful enough airborne radar and medium-range air-to-air missiles (initially, the F-16 aircraft had no medium-range missiles at all);

- installation of interconnected optoelectronic systems, highly manoeuvrable dogfight missiles and an accurate formidable gun in addition to the airborne radar.

This ensured the superiority of the MiG-29 as compared with the western fighters of any type, including the F-16. The range, endurance, payload and sighting gear designed to attack surface targets were given lower priority.

The design work was initially led by General Designer R.A. Belyakov and Deputy Designer General for Projects and subsequently first Chief Designer A.A. Chumachenko. Later on, he was succeeded by M.R. Waldenberg, V.V. Novikov, A.B. Slobodskoi, S.P. Belyasnik, and, as far as some of versions are concerned, by N.N. Buntin and I.G. Kristinov.

Preference was given to the integral aerodynamic configuration with large LERXs. The configuration calls for a very smooth transition of the wing into the fuselage, and the latter accounts for much of the lift. Also, the effect of the air intakes and engine nozzles was taken into account.

The aircraft was fitted with two advanced RD-33 afterburning turbofan engines. The engines provided for an initial thrust-to-weight ratio of more than 1, with the combat thrust-to-weight ratio in excess of 1.5.

As before, the design process was very meticulous as testified by the fact that the only essential difference between the first prototype and the production aircraft consisted in the nose gear having been moved somewhat aft. The initial design called for work in two phases. However, the progress in the development of the Rubin airborne radar, optoelectronic sighting/navigation system, sophisticated medium-range and short-range missiles (R-27 and R-73 respectively) ensured the completion of the work in just one phase. After that, the types of the gun and ejection seat were defined, and in 1975, work started on building the prototype that was assigned code 9-12. The same code also was preserved for the initial mass-production aircraft.

The aircraft conducted its maiden flight on 6 October 1977, with test pilot A.V. Fedotov at the controls.

A large number of prototypes and flying laboratories were used in support of the tests. The official trials commenced in 1979 and ended in success in 1983, with more than 2,300 flights completed. In parallel with the tests, the Moscow Aircraft Production Association (Russian acronym MAPO) was building pilot-batch aircraft and later the mass-production aircraft.

The structure of the initial aircraft widely used composite materials.

Another feature consisted in the architecture of the avionics suite comprising two subsystems, each having its own master computer. One subsystem included the airborne radar and the other subsystem included optoelectronic sighting systems as well as navigation instrumentation and data displays. The master computers of the two subsystems were interconnected, with the provision made for accomplishing missions even in case of failure of any of the subsystems.

The MiG-29 aircraft proved to be able to perform excellent aerobatics that could not be achieved by Western aircraft, e.g. the Cobra – a dynamic manoeuvre with the angle-of-attack exceeding 90° or the Bell – the flying at a pitch angle of 90°, followed by reducing the speed to zero or even to a negative speed (backward flight).

Before the early ‘90s, production variants included the following:

The MiG-29 (9-13) is a version of MiG-29 (9-12), incorporating drop tanks, a larger internal fuel tank, a larger combat load (3 t instead of 2 t) and most of the solutions recommended in the Official Trials Report. Some of the aircraft had an integrated active electronic countermeasures (ECM) station.

The MiG-29S (9-13S) is a fighter with the upgraded radar ensuring the use of advanced medium-range active radar homing missiles and featuring a simultaneous two-target engagement capability. The aircraft boasted an improved built-in flight recorders and the anti-ECM capability. The radar subsystem included an advanced master computer, Ts-101M. Weapons included, among other things, the R-27 missile powered by a more powerful motor, the payload load grew to 4 t and the aircraft control system was improved.

The MiG-29SM is the version of the MiG-29S, featuring a TV display in the cockpit and the ability to launch Kh-29T missiles and KAB-500Kr smart bombs.

The MiG-29UB (9-51) is the combat trainer version without the airborne radar and medium-range air-to-air missiles. The aircraft is capable of dogfighting and attacking ground targets. The instructor-pilot's station is fitted with a periscope and a mirror. The aircraft has combat simulation equipment and an recorder system. The two-seat plane production was assigned to the Sokol plant in Nizhny Novgorod.

The MiG-29 (9-12P) is the version, to which several aircraft were converted for display in exhibitions and air shows. The aircraft incorporates a stack stick and equipment for flying on foreign civil air routes.

Prototype aircraft

The MiG-29 (9-14) is an extended strike capability fighter equipped with the Ryabina laser/TV system, anti-radiation missile launch equipment, Kh-25ML (MP), Kh-29L, Kh-29T and Kh-31P air-to-ground missiles, and KAB-500L and KAB-500KR guided bombs or nine FAB-500 in the case of the 4.5 t maximum payload. The aircraft’s optimization was terminated as the MiG-29M aircraft, featuring a better performance, was put to tests.

The MiG-29M (9-15) is a heavy upgrade of the baseline MiG-29, featuring a sophisticated avionics suite, the ‘glass’ cockpit, HOTAS weapons management concept, air-to-surface guided weapons, a larger number of weapon stations and a heavier weight of the weapons carried, and the fly-by-wire control system.

The aircraft features a larger fuel load, better aerodynamic characteristics and engines that are more powerful. The air intakes are fitted with the lifting screens to prevent foreign object damage to the engines. The aircraft has no louvres.

The MiG-29M is essentially made of a weldable aluminium-lithium alloy to reduce weight. The use of welding instead of riveting reduced the airframe manufacturing man-hours.

With six MiG-29Ms built, some 1,200 test flights were conducted to prove the basic design parameters and serviceability of all systems. Further efforts discontinued for the lack of funding.

The MiG-29KVP is the aircraft derived for testing take-off from a ski-jump ramp. It was expected to be used for honing arrestor-assisted landings further down the road.

The MiG-29E Skif was derived for testing a fiber-optical multiplex communication channel.

Also, a prototype aircraft with the radar absorbing coating was built, as were a number of flying laboratories to test the MiG-29M’s (9-16) radar and the RVV-AE missile and to debug the RD-33K engine as well.

The MiG-29K (9-31) is a ship-based fighter boasting 80–85% commonality with the MiG-29M.

The MiG-29K completed its maiden flight on 23 June 1988, with test pilot T.O. Aubakirov at the controls. On 1 November 1989, the same pilot took off and landed the aircraft on deck of the Admiral Kuznetsov aircraft carrier. Two aircraft logged about 100 deck landings and take-offs in total.

The tests for fitness for ship-based operations were completed successfully, but, as in the case of the MiG-29M, no further work was pursued.

There also were a number of other aircraft that did not go past the design phase, e.g. the two-seat ship-based aircraft (9-61), attack aircraft, combat trainer derived from the MiG-29M, and subsequent derivatives of the MiG-29M ranging from the MiG-29M1 to the MiG-29M4.

During the Soviet era, Moscow-headquartered MAPO and the Sokol plant (Nizhny Novgorod) had built some 1,500 aircraft in all versions. The aircraft were manufactured under state contracts, but at some time, the customer ran out of funds, and the acceptance agency stopped accepting the products.

Quite a few MiG-29s were exported and used in action, e.g. in Serbia during NATO's aggression. Following the disintegration of the USSR, many aircraft were inherited by the newly independent states. When the German Democratic Republic was incorporated into the Federal Republic of Germany, the its MiG-29 fleet entered service with the latter’s air force, but it was later ‘sold’ to Poland at a token price of €1. Czechoslovakia distributed its MiG-29s between the Czech Republic and Slovakia, and the former almost immediately exchanged these aircraft for Polish helicopters.

The MiG-29 has set a number of world records.

The effective participation of the MiG-29 in displays and air shows, reputed image of the MiG brand and overwhelming superiority of DDR's MiG-29s over NATO fighters training combat drills, along with similar drills in other countries, created advantageous conditions for export sales. This resulted in the United States having focused on improving the performance of its F-16 fighter, the key rival of the MiG-29. In particular, the F-16 was fitted with more powerful engines, active electronically-scanned array radars and sophisticated missiles. The need, therefore, arose to improve the MiG-29 and derive new version from it – the MiG-29S and MiG-29M.

MiG-29 in post-Soviet era

In the absence of governmental defence orders from 1992 through 2010, the design bureau focused on the development of export variants and maintenance of earlier-built aircraft, as the company had the relevant production facilities while the demand for aircraft remained high enough. The backlog and even completed aircraft were retained in the company's owner-

MiG-29M2 multirole fighter

ship, and the company obtained a licence for foreign trade.

The order awarded by Malaysia in 1994 was a real breakthrough, given that the country had been West-oriented. While fulfilling the contract, it was for the first time in domestic practice that many of the aircraft's parameters were designed in line with the customer's requirements. The experience turned out to be a success and continued thereafter.

At the turn of the century, the fighter fleet of West Germany's Air Force found itself in a difficult situation. The in-service F-104 and F-4 Phantom had grown obsolete, while the development of the Eurofighter Typhoon had slipped well behind schedule. Therefore, the air regiment of MiG-29s inherited from East Germany along with well-trained pilots came in handy.

For the purpose of maintenance of those aircraft, Russian-German joint venture MAPS was established to support their operation and undertake a two-stage modernisation to harmonise them with NATO standards in terms of communications, navigation and air traffic control. Additional lights were arranged for night flight in formation. The same configuration was also offered to other former Warsaw Pact countries. In addition, a larger-scale proposal was issued (MiG-29E) for installation of co-developed airborne radar and communication gear, but the programme was not implemented.

Two attempts are known to have been made to upgrade the MiG-29 without involvement of the Mikoyan Design Bureau. Israel converted a MiG-29 to the Sniper demonstrator fitted with Israeli avionics, airborne radar and weapons. In Baranovichi, Belarus furnished a MiG-29BM with advanced computers and enhanced its air-to-ground capability.

By the initiative of M.V. Korzhuyev, who led the Mikoyan Design Bureau in 1998–99, the development of the MiG-29SMT variant was launched. The programme called for a significant extension of the range through increasing the internal fuel load and adding advanced drop tanks, sophisticated digital computers, more up-to-date architecture of the avionics suite and cockpit instrumentation, latest communications, ECM and flight data recording equipment and an upgraded airborne radar.

It should be noted that efforts also were made to extend the service life of the airframe and engines and reduce maintenance costs, including dosing so through conversion to on-condition maintenance. Engine designers succeeded in introducing the FADEC system, reducing the engines' exhaust plume and increasing the engines' service life considerably. The efforts also included the development of advanced training aids, simulators and flight data analysis systems.

Today, the standing of the MiG Corporation is more stable and predictable. The corporation's orderbook has become fat enough, and the company has resumed full-rate production and performed a number of prototyping works, developed cutting-edge MiG-29 versions and laid the groundwork for the future.

Today's priority of the design bureau is to develop the MiG-29K/KUB ship-based aircraft for the Indian and Russian navies. The Indian Navy had for a long time operated two aircraft carriers with a complement of Harrier subsonic VTOL aircraft. The ships were pretty long in the tooth, and the aircraft were not effective enough. Therefore, when the decision was taken to convert the Admiral Gorshkov through-deck cruiser to a full-fledged aircraft carrier for India, a question arose regarding the type of the aircraft to deploy on the carrier and on other Indian Navy carriers to be built in the future. Following lengthy discussions, the choice was made in favour of the MiG-29K that, when compared with the Su-33, offered a better operational versatility and a lower fuel consumption. In addition, the carrier could accommodate more MiG-29Ks than Su-33s.

Specific features of ship-based aircraft:

1. Advanced landing gear with enhanced shock absorption and high-pressure tires
2. Retractable arrestor hook to snag the arrestor unit, including provision for illumination at nighttime
3. Modified wing panels, their folding capability, somewhat wider wingspan and wing size, double-slotted flaps and aileron droop for landing speed reduction
4. Modified engine, including the introduction of augmented thrust mode (up to 9,400 kgf).
5. Upgraded communications equipment compatible with relevant systems of the carrier
6. Additional corrosion protection
7. Reinforced structure of the central fuel tank and a larger horizontal stabiliser with a modified shape
8. Mid-air refuelling/fuel dump system

It is worth mentioning that the aircraft much differed from the MiG-29K tested in 1988-89. The avionics suite is advanced, including the airborne radar and cockpit management suite. Latest formidable weapons have been introduced, especially anti-ship missiles. Some of the avionics is of Indian or Western origin. The aircraft is fitted with a different version of engines, featuring a longer service life and a higher thrust. The airframe is more durable, for it is made of sophisticated structural materials. The aircraft's radar signature was reduced.

In addition to the single-seater, the MiG-29KUB two-seat combat trainer has developed, featuring a high degree of commonality with the MiG-29K, including the same avionics and weapons suites.

The MiG-29K and MiG-29KUB were used for deriving the MiG-29M and MiG-29M2 multirole fighters lacking features typical for carrierborne planes.

Further work on the MiG-29SMT has resulted in two more variants – MiG-29SMT-1 and MiG-29SMT-2. The size of the add-on spine tank has been reduced, while the avionics and weapons mix is close enough to that of the ship-based version. The two variants were expected to be derived both through the upgrade of the existing aircraft and through production of brand-new ones.

Orders for the MiG-29SMT-1 were placed by Algeria. For political reasons, however, the aircraft were returned to Russia on Algeria's initiative following a two-year operation, although the Algerian pilots told at the meetings with our specialists that those were the best aircraft ever operated by their air force. Today, the fighters are in service with the Russian Air Force, while the work on MiG-29SMT-2 is under way.

Another important programme is the modification of the Indian Air Force MiG-29 fleet to bring it up to MiG-29UPG standard.

The best performance is demonstrated by the MiG-35 being derived from the MiG-29's airframe. The idea is to make a modified Generation 4++ medium-class fighter that would be free of the 'teething troubles' and which combat capabilities would be on a par with those of the Eurofighter Typhoon, Rafale or F-35 and which would far exceed its rivals in terms of higher reliability and ease of maintenance and lower price and operating costs.

To cope with the heavier take-off weight, the engines' power has been increased. The avionics suite has new functions, especially when it comes to electronic countermeasures, and includes an AESA radar and latest optoelectronic systems. The weapons suite includes more types of weapons, a greater number of those and a heavier overall payload, while the fighter's signature has decreased.

The aircraft demonstrator had passed the flight programme as part of the tender for an advanced medium-class multirole combat aircraft for the Indian Air Force.

The programme continues in the interest of the Russian Air Force now.

The MiG-29□ was used as the baseline model, from which the MiG-29OVT all-aspect thrust vector-controlled fighter has been developed. The derivative incorporates a digital fly-by-wire aerogas-dynamic aircraft and nozzle control system and has repeatedly displayed its flying capabilities.

In addition, flying laboratories were developed to test the engine and advanced avionic and weapon systems. The training aid and simulator development and the introduction of new logistic standards and common control, navigation and communication fields continue. The designing of new aircraft versions is under way.

Customers are offered the advanced MiG-35, MiG-29M/M2 and MiG-29SMT fighters, including customized upgrade options.

MiG and outer space

It was believed in the '60s that the mass of loads taken to outer space and back to the Earth would grow as a parabolic function of time. Transportation costs were supposed to grow accordingly. The need arose for a cheaper method to take space vehicles into and from orbit. Quite an obvious solution was to use horizontal take-off and landing instead of vertical launch and landing involving a ballistic rocket, a parachute system and a retrorocket.

Such a concept provided for an easier solution to the problem of placing a space vehicle into orbit, running through the selected points with the minimum number of intermediate passes, and allowed one to change the orbit inclination angle, make a better use of the Earth velocity through the shift of the orbit entry point toward the equator and perform the orbit manoeuvre and reach the touch-down point. The development of a booster aircraft (it has not been developed to date) and the reentry vehicle proved to be a very complex technical task. In the USSR, this was even more complicated by a bureaucratic conflict between the Ministry of General Machine-Building, which was responsible for spacecraft development, and the Ministry of Aircraft Industry responsible for aircraft development. Luckily, we had G.P. Dementyev dual-hatted as deputy chief designer in the

Mikoyan Design Bureau an employee of the Moscow Aviation Institute at the V.P. Mishin-led department where leading employees of the Korolyov Design Bureau lectured.

A decision was taken to launch the development of an aerospace system, with the A.N. Tupolev-led design bureau tasked with developing the hypersonic booster plane and the Mikoyan Design Bureau with that of the experimental manned orbital aircraft (EMOA).

The development pursued by A.N. Tupolev's design bureau was not too quick and smooth. Hence, the booster aircraft programme was transferred to the Mikoyan Design Bureau for a while. Soon thereafter, however, it was decided to place the EMOA into orbit, using the R-7 ballistic rocket. The solution was expected to save costs and time, but imposed considerable mass and size limitations on the EMOA. Mind you, similar activities were under way in the United States (the Dyna-Soar programme), accompanied by a fairly extensive advertising campaign. G.Ye. Lozino-Lozinsky was appointed Project Chief Designer, and G.P. Dementyev and P.A. Shuster were appointed his deputies. The latter was also appointed head of the design bureau's newly-established branch in Dubna, where the vehicle was to be built.

The main problem boiled down in choosing appropriate structure that could ensure flying in the face of huge thermal and aerodynamic loads, on the one hand, and sufficient lift, lift-to-drag ratio and controllability, on the other hand.

The choice was eventually made in favour of an unusual aerodynamic shape in the form of the triangular highly-swept lifting cone with a flat bottom surface.

The nose section of the cone was rounded, whereas its lower part also served as the heat shield thermally insulated from the rest of the craft, while its structure did not create temperature deformation loads.

An unusual ski landing gear had four struts bypassing the screen during their retraction and ensuring landing on unpaved ground. The pilot was seated in a pressurized survival capsule. The pivot outer wing panels would be elevated in outer space and during descent, and would return to the normal position for landing. The vehicle was fitted with the vertical stabiliser and flaps for bank and pitch control. To fly in the upper atmosphere and outer space and decelerate during descent, the vehicle was supposed to use the gas-dynamic system.

The initial phase involved the development of Product 105-11 that was to be jettisoned by a Tu-95 aircraft and be capable of flying at subsonic speed and landing on unpaved ground. For this purpose, the vehicle was fitted with the RD-36K turbojet engine.

Due to a Tu-95 being unavailable, flight tests started with unassisted takeoff and landing. To implement the mode, the nose gear struts were made longer, and the skis were replaced with wheels to create the takeoff angle-of-attack. The maiden flight was made on 11 October 1976 by test pilot A.G. Fastovets, and a year later, a Tu-95 aircraft was used, with the tests completed in earlier 1978. Since the Buran spacecraft development started then, Programme 105-11 was terminated and Product 105-11 was handed over to the aviation museum in Monino.

The results produced were used afterwards in the development the Bor-series orbital vehicles and the Buran spacecraft.

MFI multirole fighter

The programme was launched in the early '80s, mainly because the United States kicked off their new-generation fighter programme that resulted in the F-22 Raptor multirole aircraft. We were tasked with designing an aircraft surpassing the F-22 in air battle, but also being able to attack ground targets. In addition, the aircraft was supposed to carry new-generation tactical fighter weapons and embody advanced technologies that also could be used in applications other than aircraft.

In this connection, a decision was taken to organise the efforts in a new manner subject to approval by the government of the Integrated Programme covering all basic components, technologies and research activities. The Integrated Programme was expected to be led by the Mikoyan Design Bureau, with G.A. Sedov appointed chief designer.

The aerodynamic configuration of the aircraft was thoroughly tested, using wind tunnels, test benches and flying models to achieve good manoeuvrability and high lift-to-drag ratio on both subsonic and supersonic flights. In addition, steps were made to reduce the aircraft's signature, including doing so through internal weapons carriage. As a result, the choice was made in favour of the canard configuration with the adaptive delta wing.

Close attention also was paid to the development of the new-generation AL-41F engine boasting a high thrust-to-weight ratio in take-off and combat modes, coupled with long range on subsonic and supersonic flights and with the feasibility of steady non-afterburning supersonic flight. Both the airframe and the engine were designed to have a long service life. Provision was made for engine thrust vector to be controlled. Before being flown on the MFI, prototype engines had been tested on special test benches on board subsonic and supersonic flying laboratories derived from the MiG-25.

Special attention was paid to ergonomics and comfort for the pilot. The aircraft featured high endurance at high g-loads.

The flight control system incorporated multiple control surfaces, and a combined control was exercised by the aerodynamic surfaces and swiveling nozzle.

The aircraft was expected to be fitted with new-generation avionics, including a number of AESA radars for 360° coverage.

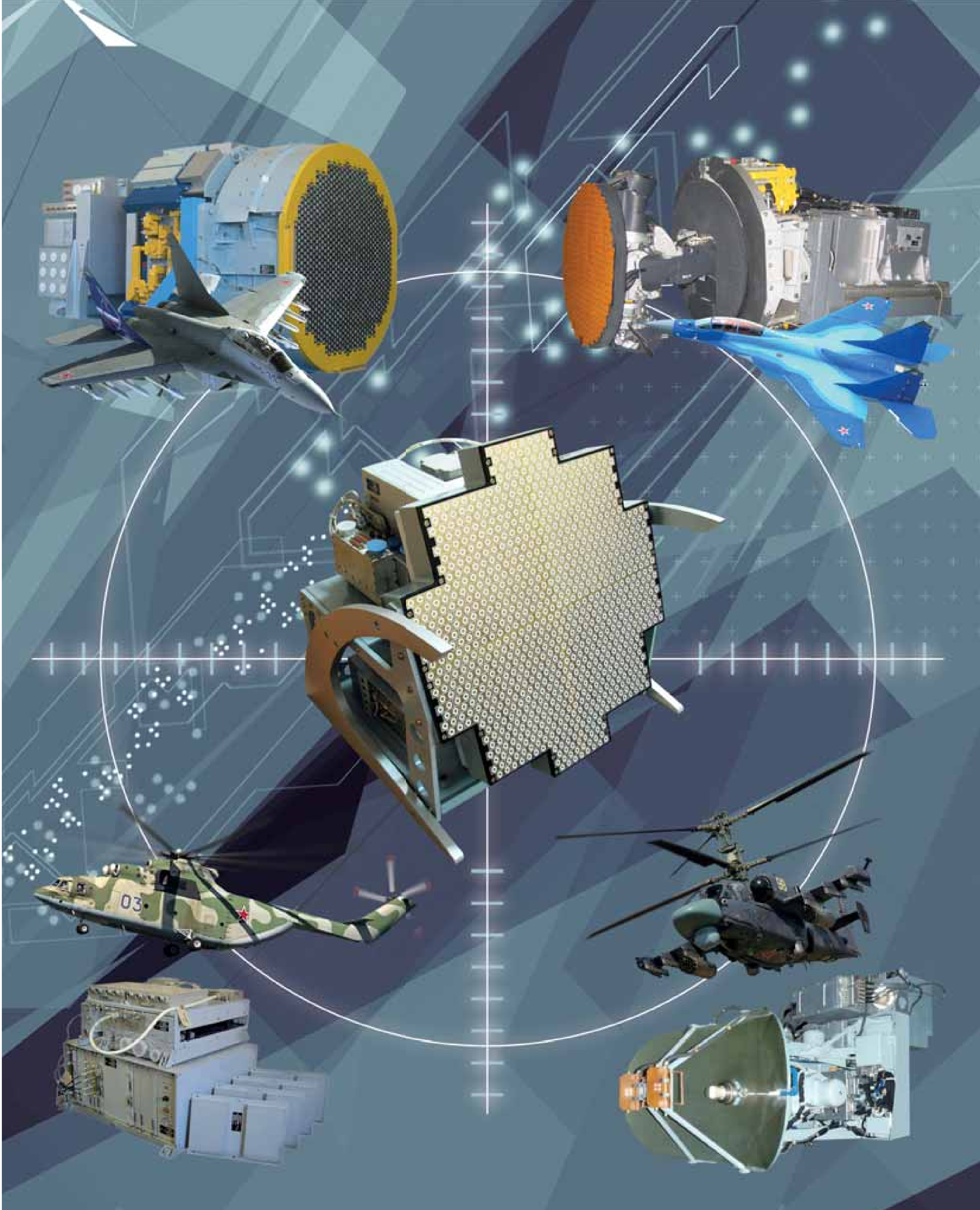
Development of new-generation air-to-air and air-to-surface guided weapons started to fit the fighter.

The aircraft passed all design work phases, with a prototype, designated as 1.44, built by the prototype production facility. The prototype completed its maiden flight on 29 February 2000, flown by test pilot V.M. Gorbunov. The aircraft was powered by standard engines, and the manufacturer plant in Nizhny Novgorod began to manufacture the first batch of prototypes.

Regrettably, the funding of the programme and, hence, the programme itself were discontinued.

Today, the design bureau operates as the Mikoyan Design Bureau Engineering Centre of the MiG Russian Aircraft Corporation. It has been led by Vladimir Barkovsky, Ph.D., since 1999.

At present, the MiG Corporation is performing full-rate production of the MiG-29K/KUB and MiG-29M/M2 fighters and upgrading the MiG-31 (MiG-31BM) and MiG-29 (MiG-29UPG and MiG-29SMT). Work is in progress on new derivatives of the MiG-29 and MiG-31. The corporation can supply MiG-35 multirole fighters and is developing cutting-edge planes and UAVs.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The Radio-Electronic Technologies Concern is a new player on the global market of radio-electronic solutions for government and business, with the company facing bright technological vistas and having a long-term corporate development strategy. The concern offers up-to-date radio-electronic products based on innovative Russian technologies and designed for outer space, aviation, naval and army applications. The Radio-Electronic Technologies Concern sports a wide range of products for use in the medical, power generation, transport and other spheres. The company's steady growth and good financial standing bolster its commitment to its global security mission with reliance on the best traditions of the Russian radio-electronic school of thought. The Radio-Electronic Technologies Concern was set up in 2009. It comprises 97 subsidiaries throughout Russia.

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