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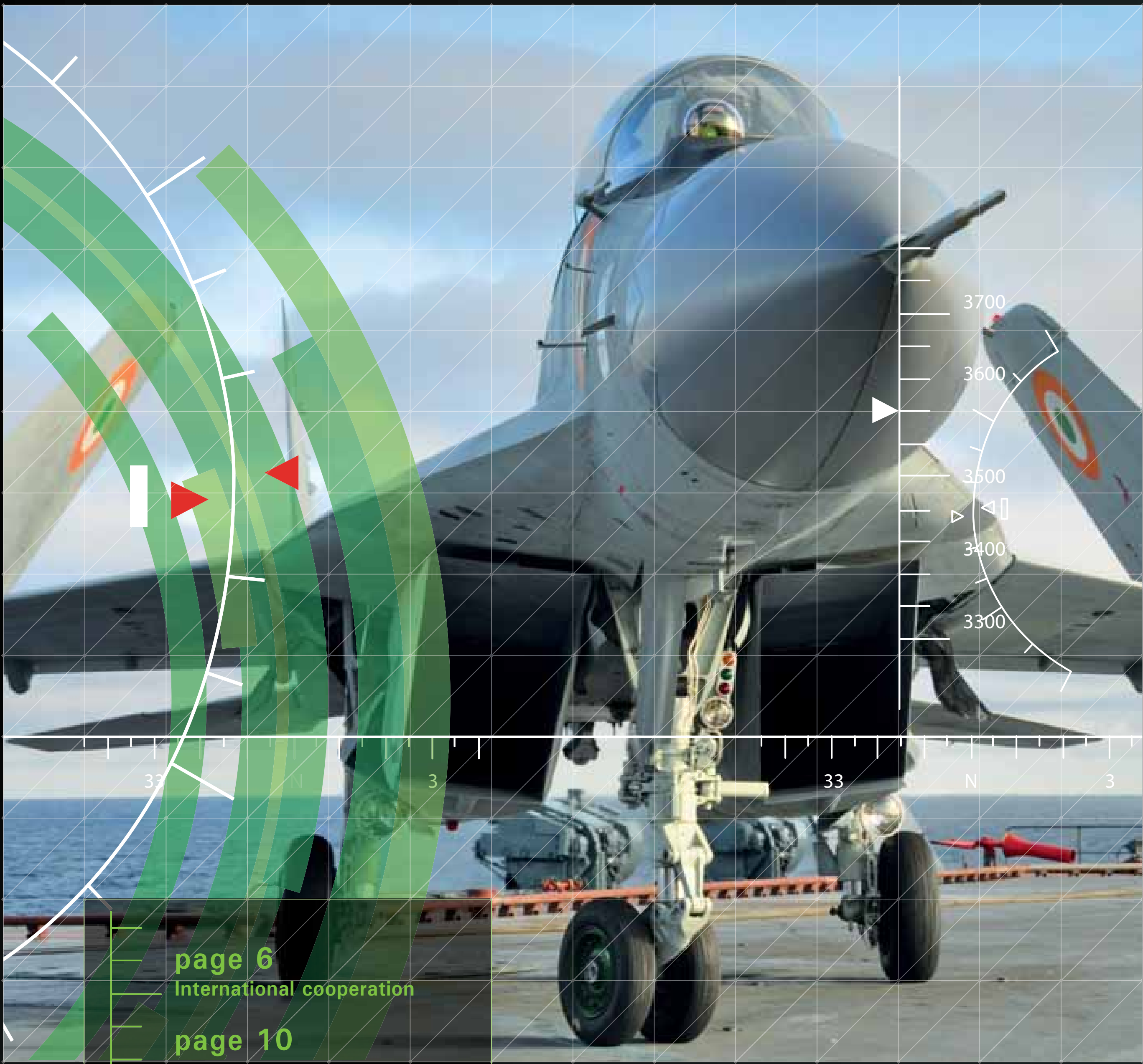
RADIO ELECTRONIC TECHNOLOGY



KRET

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To organisers, participants and guests of Aero India 2015 international air show

Anatoly Isaikin,
Director General, Rosoboronexport JSC

Dear colleagues and friends!

On behalf of Rosoboronexport JSC, the only Russian Federation governmental intermediary for export of military and dual-use products, technologies and services, I am greeting and congratulating you on the opening of the 10th Aero India International Show on Aerospace, Defence, Civil Aviation, Airport Infrastructure and Defence Engineering (Aero India 2015).

Since its inception, the show in Bengaluru has become a major international venue dedicated to air force armament and other materiel, equipment for commercial aircraft and rocket and space industry, and air defence assets. The innovative nature of Aero India enables its participants to display the intellectual and production capabilities of their nations' defence industries and its guests to be impressed with the breathtaking aerobatics performed by military aces at Air Force Station Yelahanka.

Rosoboronexport is a long-time participant of the air show in Bengaluru. Our cooperation with India is based on due account of the most promising lines of development and expansion of the military technical cooperation that has evolved into strategic partnership a long time ago. A case in point is the joint work of Indian and Russian specialists under key aircraft programmes on the development of a multirole medium-range transport plane and a fifth-generation fighter.

I am certain that the Aero India 2015 show will lay the groundwork for future export contracts and facilitate the development of high-technology segments of defence industry.

I wish the organisers, exhibitors and guests of the show fruitful work and successful business contacts that will embody in the new mutually beneficial projects in the future. Award contracts to Russian manufacturers, buy Russian weapons and strengthen your defence capabilities.

Radio Electronic Technology

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Cover photo: MiG-29KUB on the flight deck of INS Vikramaditya

Criterion of truth

Any international air show is an excursus to the past, an appraisal of the present and a vision of the future. To a certain extent, it is a criterion of the truth as well. The truth in science and technology, economy and politics, international and human relations. This fully applies to the Aero India air show that sets the standard of military and commercial aviation development both in Southeast Asia and in the whole of Asia-Pacific region.

Russia and India share five decades of mutually beneficial cooperation and unity of political opinion, sincere friendship and interpenetration of cultures. The great Indian statesman, father of the present-day Indian statehood, Jawaharlal Nehru, said: "The past is always with us and all that we are and what we have comes from the past. We are its products and we live immersed in it. Not to understand it and feel it as something living within us is not to understand the present".

Today, India and Russia are equal partners in the development of new-generation aircraft, and the importance of the state of affairs like that cannot be overrated. The synergetic effect of the cooperation will manifest itself not only in specific products. No doubt, it will give impetus to the industries of both countries and their applied science. Another great man, Albert Einstein, maintained: "The truth is what stands the test of experience. The search for truth is more precious than its possession". Let us trust in the wisdom of the great minds!

Oleg Kustov,
Editor-in-chief,
Radio Electronic Technology Magazine

Russia showcases its finest arms and commercial technological developments in India

ALEXANDER MIKHEEV
CEO of Russian Helicopters,
Delegation Head for State
Corporation Rostec,
Aero India 2015

It is pleasing to say that relations between the Russian Federation and the Republic of India constitute a strategic partnership – and not simply in name, this is a reflection of their real significance. Today, as Russian President Vladimir Putin noted during his state visit to India in December 2014, the strengthening partnership with India is an essential priority in our country's foreign policy.

This relationship has a long history – the first foundations were laid by Tver merchant Afanasy Nikitin, who visited India in the 15th century. That sparked the start of trade relations, which today run to billions of dollars per year. In military-technical cooperation alone, contracts worth about 65 billion dollars have been signed with India since 1960. This year marks the 55th anniversary of the first steps in military-technical cooperation between Russia and India. This is a significant anniversary. In 2013, deliveries to India by Rosoboronexport, the country's official exporter of military products and arms, exceeded 3.6 billion dollars in value. This puts it in a solid first position among the importers of Russian military products. In 2014, Rosoboronexport confirmed this status.

However, trade with India involves a great deal more than solely military-technical cooperation.

TRADE, PRODUCTION, HIGH-TECH

The latest, 10th International Aerospace Exhibition Aero India 2015, at Air Force Station Yelahanka, Bengaluru, also facilitates the further broadening and strengthening of cooperation between Russia and India. Global aviation leaders from various countries across the world are taking part in the exhibition, and Russia is the largest participator.

India is a traditional partner to the companies that today form part of State Corporation Rostec, and is one of the most important parts of the world that imports Russian-made products. Our cars, military and commercial planes and helicopters, and other high-tech products are well known here, and are in demand among Indian customers and consumers from other South-East Asian countries. Over 30 Rostec organisations, including Russian Helicopters, United Engine Corporation, Rosoboronexport, Kamaz, Concern Radio-electronic technologies (KRET), RT-Chemical Technologies and Composite Materials, VSMPO-AVISMA, Roselectronics and others will be showcasing their latest developments at Aero India 2015.

Russian production facilities are engaged in fruitful cooperation with Indian companies. For example, VSMPO-AVISMA supplies titanium-alloy based products to various different sections of the Indian aerospace company Hindustan Aeronautics (HAL), including HAL Aircraft Division, which produces components for the Airbus A320, and to HAL Helicopters. VSMPO-AVISMA is also working in close cooperation with ISRO LPSC (in Bengaluru) on space exploration programmes, and with BHEL in the electricity and power sector. Today, the corporation is engaged in negotiations on supplying titanium products to the shipbuilding section of the company Larsen & Toubro (L&T).

RT-Chemical Technologies and Composite Materials is viewed as a partner in developing and producing tail sections and glazing for MTA planes. HAL is the Indian partner in the project. A subsidiary of the Eastern Coal Chemistry Research Institute (VUKhIN) and its Indian partners are working to develop and launch works in the metallurgical and mining industries, in particular with Indian state company SAIL (Steel Authority of India Limited).

Virtually every Russian plane and helicopter that takes to the skies is equipped with avionics produced by KRET, which comprises 13 separate enterprises. KRET showcased its latest developments at Aero India 2015, including a laser-optical suppression station that is used in the President-S (BKO) airborne defence system. It offers high-quality protection against infrared guided missiles. Given the heightened risk of terrorists using man-portable air defence systems (MANPADS), this offers vital protection to both military and commercial planes and helicopters.

Kamaz is one of the companies that Rostec is representing. Kamaz Vectra motors was established in Hosur six years ago. This joint venture is a truck assembly plant using locally-sourced components to build medium and heavy Kamaz trucks, and has a capacity of 5,000 trucks per year. In December 2013, Kamaz bought out its partner's stake – becoming the sole shareholder in the enterprise, and in 2014, the company was re-named Kamaz Motors. Since the joint venture was founded, Kamaz has shipped 710 kits. The Indian government's support in organising the targeted placement of state orders for Kamaz products for the law enforcement and other state agencies would offer substantive support to Kamaz in India, and the state agencies would receive reliable and technologically advanced vehicles. This would have an even greater impact – creating new jobs in assembly and boosting demand for Indian-made components.

RELIABLE HELICOPTERS FOR A LARGE COUNTRY

One of the key areas of business cooperation between Russia and India is in helicopter building and involves Russian Helicopters – the only company in Russia involved in designing and producing of helicopters. The companies that today form part of Russian Helicopters have been supplying helicopter technology to India for 50 years: cooperation between the two countries began in the 1950s.

The first helicopters that took to the skies in India were Soviet multirole Mi-4s. India bought 110 Mi-4s, creating the most powerful helicopter fleet in the region. The Indian Air Force was one of the first to own the Mi-8. A total of 128 helicopters were delivered. Later came the Mi-26 transport helicopter, the military Mi-25 and Mi-35, the Ka-28 and Ka-31, and the latest Mi-8/17 helicopters – including the Mi-17V-5.

Mi-28NE 'Night Hunter'

India's commercial aviation firms operate Mi-172 helicopters, which meet all the requirements of, and are certified by, the country's aviation authorities. Two of these helicopters were delivered to India in August 2012 for Pawan Hans Helicopters Ltd. state enterprise. Russian Helicopters is working alongside its Indian partners to develop new projects to deliver about 8–10 various types of Mi-172 helicopters to a series of private companies.

Mi-171A2 equipped with 'glass cockpit'

Cooperation between Russia and India in the helicopter industry is principally focused on the military-technical segment, and Russian Helicopters' partner Rosoboronexport has concluded a contract for the delivery of 151 Mi-17V-5 helicopters. Experts say this helicopter is unparalleled in search and rescue operations in India's mountainous regions. To date, 128 of the 151 helicopters specified in this contract have been delivered, and another 23 are set to be delivered by the end of 2015.

Today, Russian Helicopters is looking at establishing production of the Ka-226T light helicopter in India, under a request made by India's authorities. If Rosoboronexport and Russian Helicopters are successful, then they would also be willing to undertake a more ambitious project – working jointly to develop a new helicopter for medevac, search and rescue and other operations, based on the Ka-226T. The Ka-226T has already undergone tests in India, and has demonstrated its excellent operation in India's high mountainous areas and hot climate. The option of setting up production of various helicopter units in India to reduce costs is also being considered.

In response to the growing fleet of Russian-made helicopters in India, Rosoboronexport and Russian Helicopters will establish a training centre for pilots and engineers. The joint maintenance and repair centre in Chandigargh makes it possible to carry out complex work and imrpove the quality and speed of after-sales service and maintenance for Russian-made machines in the region.

The globalisation of world markets is part of today's reality, and therefore one of Russian Helicopters' key tasks is to become more competitive – through creating an optimum supply chain, and ensuring high-quality after-sales service for helicopters in the customers' own countries. Where, previously, Russian Helicopters' service and maintenance projects were narrowly limited to commercial helicopters, they now also encompass military helicopters. In October 2014, Russian Helicopters received approval to enter into external trade activity with military goods – exporting spare parts, components, and technical documentation for the helicopter equipment supplied, modernising and creating maintenance and repair centres abroad. Russian Helicopters is now in an excellent position to offer the full range of after-sales service to all Russian-made helicopters.

Russian Helicopters, and other Rostec companies, plan to continue this mutually beneficial dialogue with their Indian partners at Aero India 2015. We have a multitude of very promising projects, all of which could help bring Russian-Indian trade and economic relations to a qualitatively new level, and significantly expand their scope.

Combat-reconnaissance helicopter Ka-52 'Alligator'

KRET presents and recommends...

The Aero India air show remains rightly reputed as the key defence technology exhibition venue of South Asia. A case in point is not only the impressive list of the companies attending, but also the list of the official delegations to the show, which members offer a rather competent assessment of the prospects facing the development of India's military capabilities.

India has always acquired cutting-edge products of the global defence industry, owing to which its armed services are among the most advanced ones in the region. Over the past decade, the emphasis of India's military-technical cooperation with its partners has been shifted from the seller – buyer relations to full-fledged partnership in joint combat gear development.

Good case in point is the Su-30MKI multirole fighter, which configuration was shaped by the two countries' engineers two decades ago, which made the aircraft a 'multinational' product owing to a large-scale introduction of avionics and other equipment from various manufacturers.

The high-tech transfer continues today. At the Aero India 2015 show, the Concern Radio-electronic technologies will unveil the latest products of its subsidiaries, including the Zhuk-AE active electronically scanned array (AESA) radar in the FGA35 variant. The radar is designed to equip future new-generation aircraft. It has an AESA allowing multiple-target simultaneous tracking by means of electronic control of the radar beam's position. The Zhuk-ME from the Phazotron-NIIR Corporation (a subsidiary of the Concern Radio-electronic technologies) is superior to the existing analogues in performance, while having smaller dimensions and a lighter weight.

Another novelty is the President-S electro-optical countermeasures laser system developed by the Ekran research institute. The President-S is designed to protect light helicopters, including the export-intended Mi-28NE attack helicopter, from man-portable air defence systems.

In addition, the joint display ground of the Concern Radio-electronic technologies will show the KARAT-B emergency flight recorder system developed by the Aviaavtomatika company to fit the MiG-29K fighter, as well as the MFI-10-7V and MFI-35 multifunction liquid crystal displays and LINS-100RS strap-down inertial navigation system – all from the Ramenskoye Design Company. The Ramenskoye Instrument Plant will exhibit a similar system of its own – the INS-2000.

The Gradient research institute – the KRET's prime developer of advanced ground-based electronic warfare systems – has prepared for those concerned information materials covering a wide range of EW systems and their components.

KRET Delegation Head at Aero India 2015 is deputy Director General Igor Zolotov.

Our target is a world-class concern!

NIKOLAI KOLESOV
Director General,
Concern Radio-electronic technologies JSC

The Concern Radio-electronic technologies (Russian acronym – KRET) is the unique association of Russian instrument industry players. It comprises in excess of 100 radio-electronic industry organisations and companies in 29 regions of Russia, employing about 60,000 personnel. According to such leading consulting companies as Strategy Partners Group and Frost and Sullivan, KRET's share of the domestic electronic warfare (EW) and weapon control market accounted for almost 94% in 2012.

In 2014, the concern got an international rating for the first time since its establishment. According to the authoritative US weekly Defense News, the concern rated 52nd on the Top 100 list of the world's major defence contractors. This is yet another proof of the competitive edge of Russian instrument and radio electronics manufacturers and testimony to the effectiveness of the Rostec-chosen approach to the integration of the industry's majors under the common brand name of KRET. The concern is not about to rest on the laurels and has already started adjusting its development strategy. The emphasis has been placed on diversification, commercial products, integration of the technological capabilities of its subsidiaries and skilled workforce recruiting.

These days, KRET is a vertically integrated company with a complete range of competencies in military and commercial radio electronic system development. The company exports its products to 60 countries. Its high-tech products are second to none as far as a number of characteristics are concerned. A good case in point is the identification friend-or-foe (IFF) system. At present, the world uses only two IFF systems for national identification – one made in Russia and the other in the United States. Many countries operate the Russian-developed Kremny-2 IFF system, while the Russian military's weapons systems carry the Parol IFF system. The latter's export variant, designated as 60R, is on a par with the US-manufactured Mark XII system in service with the militaries of the United States and other NATO member states. The modernisation of the 60R system resulted in the 40R IFF system featuring improved performance. KRET continues the development of IFF gear allowing beyond-the-horizon IFF as well as IFF of units on the battlefield, including individual servicemen.

During the 22nd Winter Olympics in Sochi, Garmon mobile small-size radars were tested with success, while performing aircraft acquisition, tracking and IFF'ing and feeding the resultant flight path data to automated control systems.

The concern is Russia's major developer and manufacturer of military avionics and is active in introducing innovations in the commercial aircraft segment of the market. In particular, the development of an avionics suite based on integrated modular avionics is under way. The advanced avionics are designed for cutting-edge planes, including the MC-21. The share of KRET's products in the airliner totals about 50% and tends to increase up to 80%. KRET's subsidiaries have developed avionics to equip the MiG-29K/KUB fighters as well as Ka-52, Ka-60M, Mi-171A2 and Mi-28N helicopters. Work is under way on upgrading the avionics suite of the Be-200 amphibian and Yak-130 combat trainer.

The KRET joint stock company develops avionics for the Russian-built PAK FA fifth-generation fighter and future PAK DA long-range bomber as well.

The concern unveiled its latest heliborne radio electronic equipment achievements – an integrated modular avionics suite – at the 7th HeliRussia 2014 international helicopter show and Farnborough 2014 air show. The equipment in question is designed for the future high-speed helicopter. The Phazotron-NIIR Corporation, a subsidiary of KRET, exhibited the Arbalet FH-01 multifunction radar designed for the Ka-52 helicopter.

Another avionics-pertaining line of work pursued by KRET is the development of ultra-wideband antenna systems based on active electronically scanned arrays (AESA). The technology has been used with success as part of the radar carried by the MiG-35 fighter. It allows tracking numerous targets owing to Doppler beam sharpening, acquiring and locking on airborne and surface targets in the lookup and lookdown modes and guide missiles to them, and handling navigation tasks as well.

KRET has worked out proposals for production of avionics to fit unmanned aerial vehicles (UAV). The UAV equipment development technological level is mostly on a par with that of relevant foreign technologies, while exceeding them as far as EW equipment is concerned. Work is under way to develop radio emitting object precision-positioning gear, powerful ultra-wideband receive-transmit active phased arrays, optronics using radio photonics elements, high-performance microwave signal analogue-to-digital/digital-to-analogue converters, just to name a few. The measures being taken in support of the development of the above technologies make up the basis of the concern's participation in programmes on the development of UAV-borne EW equipment. In so doing, close attention is being paid to automatic control, flight navigation, information management and avionics systems designed for various types of aircraft.

KRET is the Russian defence industry leader in EW system development and production. Its subsidiaries have supplied the Russian Defence Ministry with numerous advanced types of radar intelligence, protection and electronic countermeasures systems, including the Avtobaza upgraded emitter locating/electronic intelligence system. Its purpose is passive detection of emitting radars, airborne ones in the first place,

MiG-35 fighter with AESA radar

including weapon guidance and low-altitude flight control radars. The Avtobaza feeds the signal parameters and coordinates of emitting enemy radars to the automated control centre. The system is in service with the Russian Army and has been offered for export. According to the Western media, the Iranian military used the Avtobaza to wrestle the control of a USAF Lockheed Martin RQ-170 Sentinel UAV and have it landed in Iran.

Concept of avionics for unmanned helicopter

Printed circuit board automatic assembly line

The concern runs series deliveries of cutting-edge high-tech ground-mobile EW systems to combat units. The systems perform high-precision ELINT, analyse the type of signals emitted and suppress hostile command-and-control and weapon guidance systems in an effective manner, which prevents the opponent from acquiring targets and cuing guided missiles in on them. At present, the company is conducting R&D on advanced ground-based systems designed for electronic countermeasures (ECM) against strike aircraft radars and target designation and guidance system. The systems under development feature enhanced immunity to the enemy's counter-countermeasures.

In 2013, the latest fixed-wing and rotary-wing aircraft individual defence aids suite (DAS) based on the L-370-3S active jammer entered service with the Russian Air Force (RusAF). The suite is supplied for use on board Mi-8 and Ka-52 helicopters and Su-25 attack aircraft. Its versions slated for transport helicopters and planes have completed their trials. The export variant of the L-370-3S is designated President-S. It can defend any aircraft it equips from surface-to-air missiles (SAM) launched by up-to-date man-portable air defence systems (MANPADS). The system comprises a radar/laser warning system, an incoming missile warning system and a radio-frequency/electro-optical jammer. The President-S DAS allows an increase in the survivability of aircraft of various types by 25–30 times.

In 2014, KRET productionised air force group protection heliborne EW systems capable of effective suppression of virtually all current SAM system and interceptor aircraft radars and, hence, are capable of supporting strike aircraft packages flying within the breakthrough area.

KRET's subsidiaries also have developed a range of other active ECM systems and suites, e.g. an electro-optical countermeasures laser system, a towed active radar decoy and disposal jammers. All of the products have been introduced to RusAF fixed-wing and rotary-wing aircraft weapons suites and have been exported as well. Any country, which is not subject to restrictions on military product deliveries, can order the EW gear.

Under the State Defence Acquisition Programme, the concern has fulfilled a Russian Air Force-placed contract for fourth-generation multifunction EW systems designed to fit tactical fixed-wing aircraft. They provide them individual protection from enemy interceptors and AD assets. The systems in question differ

Krasukha-S4 EW system antenna

from their previous-generation predecessors in a layered multiprocessor control, signal processing and ECM generation system using digital methods on a large scale. Active ECM emitters are based on high-power active antenna arrays.

The routine fielding of up-to-date KRET-made EW gear with combat units enables the armed services quickly to provide coverage for friendly forces, command posts, AD and space defence assets and high-value industrial, administrative and political installations. To cap it all, the personnel employed by the concern work on the cutting edge of progress, already developing dual-use hardware, including the one reliant on exclusive research in the field of radio photonics. Based on such equipment, one can make a quantum leap in terms of high technologies for future EW systems. It is worth mentioning that KRET will complete over 180 R&D programmes under the State Defence Acquisition Programme in 2015.

High on the concern's priority list is its production facility modernisation programme, under which 21 projects were launched by KRET's subsidiaries in 2014. The overall investment totalled 25.8 billion rubles. Three production facility technical upgrade programmes have been complete. In all, 15 plants, research institutes and scientific/production centres of the concern have made efforts under the production facility reconstruction and technical upgrade programme. All of the concern's products shall rest upon a common technology basis.

The above transformations will ensure product line diversification, an increase in the volume of commercial products and a market expansion. Systemic change to the corporate management will facilitate technology interpenetration in the military and civil segments. The share of commercial products in the output of the holding company's subsidiaries is supposed to reach 50% by 2025.

The commercial sector development is to pave the way for the concern's subsidiaries to new markets, including foreign ones. Our strategic objective is to become a competitive integrated avionics and EW equipment supplier. We are certain we can attain the objective!

Cutting-edge technologies for EW materiel development and production

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Today, there are three basic groups of technologies intended for the development of electronic warfare (EW) systems:

- technologies at the level of EW systems themselves as elements of radio electronic systems;
- technologies at the level of basic subsystems of EW systems;
- technologies for developing electronic componentry of EW materiel.

The technologies in the first group determine the system architecture of EW systems as far as their integration in higher-level systems is concerned. With the traditional architecture, there is only informational integration – swapping of data. However, analysis of radio electronic system design concepts has shown that the hardware-integrated approach to EW materiel design is the best.

The basic lines of implementing the hardware-integrated approach are as follows:

- development of an integrated receive-transmit system based on ultra-wideband antenna and T-R modules supporting the operation of the system's informational channels across the whole frequency range;
- development of an integrated computer system based on commonised computing modules;
- development of integrated data transfer channels based on high-performance telecommunication systems with commonised gateway-to-gateway protocols allowing transmission from different sensors in a single format in real time.

The basis of the 'brains' of the integrated system is made up of the distributed computing and programmable communication media. The former is of open architecture and modular structure and is developed as a parallel distributed signal and data processing system based on multiprocessor computers, while the latter is based on programmable multichannel switchboards distributing signal streams from sensors to processors and being capable of situational communication reconfiguration.

Large volumes of data circulating via the system's channels pose stringent requirements to the capacity of signal and data processors, which is to equal about 10 billion operations per second.

The architecture of the EW system integrated with an upper-level radio electronic system is 'open' and is based on the modular design of the EW system's hardware elements. Transition to a system based on commonised modules allows a sharp drop in the hardware and informational redundancy, thus improving the system's weight and dimensions by 30–40%, increasing its reliability by two to three times, slashing its power consumption by three to four times, reducing the system's development and production costs by four to five times and speeding up the development by two to three times.

The design of the future EW system will depend on the wideband/ultra-wideband active phased-array antenna systems, wideband digital signal recorder and playback devices (DRFM technologies), high-performance digital computing modules with artificial intelligence systems, making up the foundation of the second group of EW technologies.

Mention should be made that active phased-array antenna technologies best meet the conflicting requirements for higher combat effectiveness and lower observability of combat vehicles and other military equipment.

The system technology of developing solid-state active phased-array antennas includes the following three groups of interrelated technologies:

- development of ultra-wideband (operating frequency range in excess of three octaves) twinpolarisation steerable antenna systems;

- development of ultra-wideband solid-state T-R modules; development of small modules for microwave filtering and decimetre, centimetre and millimetre band frequency conversion;
- development of digital delay lines with a digitisation of several nanoseconds.

Usually, solid-state gallium-arsenide and gallium-nitride amplifiers are used as active elements of active phased-array antennas of present-day EW equipment. This allows a weight reduction of 1.5–2 times, a 2–3-times increase in reliability, an efficiency increase of 1.5–3 times and an extraneous noise drop by 2–3 orders of magnitude as compared to the use of TWTs.

Digital signal recording and reproduction devices based on the DRPM technology allow both the generation of signals and interference of virtually any form/structure and perform their optimal real-time spatial-temporal processing. DRFM-based signal processing modules allow a novel approach to the development of integrated EW systems, having slashed their weight, size and manufacturing labour intensity owing to standardised components complaint with the versatile VITA 46 and VITA 48 high-performance digital equipment standards. The data communication throughput in the units compliant with the standard exceeds 10 GB/s, which ensures the required data communication volume among the digital modules of the EW modules.

In addition, the development of future EW systems will necessitate drastically advanced electronic componentry. To date, there have been industrial technologies designed for multifunction wideband and ultra-wideband modules of future EW systems based on multilayer microwave printed circuit board (PCB) with a simultaneous reduction in weight and size and an increase in reliability. Using the deep integration of microwave devices with control circuits and digital signal processing, they allow manufacture of virtually the whole range of EW modules, while ensuring a reduction in weight and size by several times, a drop in manufacturing labour intensity, a 5–15-times reduction in the EW hardware cost compared with the widespread chip assembly technology using ceramic substrates and thin-film technology in a titanium case.

The Concern Radio-electronic technologies is intent on making a quantum leap in the technological sophistication and characteristics of its future products by means of balanced development of the afore-said technology groups. Actually, this will ensure the transition to a new generation of EW materiel commonised on the basis of the scientific and technical progress made in aircraft development. The results, which are to be produced by the development of the future wideband high-performance heliborne EW system and small-size commonised digital-analogue T-R modules for ultra-wideband active phased-array antennas, will serve the technological basis for attaining the objective.

Multifunction microwave module design and test automation system

Approximate high-technology EW module layout

Electronic technologies in Russia

KEY COMMERCIAL AVIATION PROJECT

A prototype MC-21 aircraft will be built for flight and static tests by the end of 2015, the first test flight will be carried out in the first half of 2016, and the first Russian airliner will be launched in mass production in 2017. This was proved at a meeting in Irkutsk, which involved Russian Minister of Industry and Trade Denis Manturov. "The entire programme on the MC-21 is being implemented strictly on schedule. The installation of the manufacturing line will be completed in late May. This gives us confidence that the aircraft's first flight prototype will be ready in 2015," said Manturov.

As compared to any existing versions of this class, the MC-21 provides greater comfort for passengers due to wider fuselage and interior layout, enabling faster boarding and landing of passengers. The new aircraft has improved interior climate, created by an advanced air humidifying system. In addition, the MC-21 enjoys improved aerodynamics and lower weight, which was achieved by using cutting-edge technologies and innovative materials.

About 40% of the avionics and 90% of the software is developed for the MC-21 by the Concern Radio-electronic technologies (KRET), a division of the Rostec Corporation. The Aviation Equipment Holding, another Rostec subsidiary, will supply cutting-edge aviation systems and landing gear. In general, the state corporation is going to produce up to 80% of the MC-21's airborne electronics.

The total amount of composites, applied in the MC-21, is the highest among all existing aircraft of the class. By widely using these state-of-the-art materials, the designers will be able to reduce the weight and make a longer wing, which will enhance the aircraft's aerodynamics. The overall share of composites will amount to 30 to 40 per cent. Nevertheless, increased requirements are imposed to their reliability and durability.

The airliner is going to be powered by the new-generation PD-14 engine, which is currently under development. Intended for short- and middle-haul airplanes with 130 to 180 seats the new power plant outruns its best counterparts and is on a par with advanced foreign engines of the class.

Denis Manturov believes the market prospects for the MC-21 are optimistic. "The interest in purchasing such airplanes is high. The advantage in price, including that after the ruble's decline, has risen. As of today, we have already inked 175 prepaid contracts for the aircraft. The certificate of the Interstate Aviation Committee is to be obtained in late 2017 – early 2018. The first deliveries under the contracts will begin in 2018," said the Minister.

KRET AND UWCA TO JOINTLY DEVELOP UAV AVIONICS

KRET and the Ural Works of Civil Aviation (UWCA) have signed a deal to cooperate in the development and production of avionics, their components and subsystems for new and upgraded unmanned aerial vehicles (UAVs). The agreement was inked at the 3rd international forum Engineering Technologies 2014.

The collaboration implies development and introduction of integrated aircraft systems for promising and existing UAVs. Thus, KRET will develop the aircraft navigation system and carry out other projects.

"KRET has some key competences to meet the major challenge of forming in Russia a world-level technological potential for future unmanned aerial vehicles," said the company's Director General Nikolai Kolesov. "The concern is developing all avionics systems for military and civil UAVs. It is unified equipment for a UAV of any type, military and civilian, fixed- or rotary-wing."

Under the agreement, KRET will develop and manufacture new avionics suites and relevant software, as well as certify and integrate them in UAVs. The concern will support the avionics on all stages of their life cycle, including further improvement.

In cooperation with KRET, UWCA will work out design specifications for new avionics suites and bench-test them.

DEVELOPMENT VECTOR FOR DUAL-PURPOSE SYSTEMS

KRET and the Advanced Research Foundation have agreed to implement an advanced sci-tech project, named Development of the Radio-Photonics-Based Active Phased Array Radar (ROFAR). The project implies building a new specialised laboratory and developing a versatile technology that would form the hub of new-generation radars and EW systems. The investments in the project will amount to 680 million rubles.

"Nanophotonics is a promising field of research, which will soon determine the vector of dual-use systems' development in advanced countries," said KRET's Director General Nikolai Kolesov. "With the help of cutting-edge technologies as soon as in the 2020s we will be able to make efficient and advanced transcieving devices, radars and electronic intelligence and electronic countermeasures systems, which would replace the existing lineup."

The laboratory will be set up at KRET's facilities. Making use of the concern's test benches, it will ensure all the necessary conditions for research. Among other things, the laboratory will have the 'clean room' environment with a minimum level of dust, microbes and chemical vapors.

Dmitry Zaitsev, Ph.D. (engineering), deputy general director for advanced research of the Phazotron-NIIR Corporation, has been appointed as research manager. State investments worth 680 million rubles are expected to be allocated to the innovative project.

The laboratory will primarily be engaged in design and production of a new-generation AESA, which key elements will be made using the principles of radio-photonics. They would reduce the equipment's weight by 1.5–3 times, increase its reliability and efficiency by 2–3 times, as well as raise the scanning speed and resolution by tens of times.

In case of success, the technology would open up new vistas in improving the performance of 'smart skin' for advanced Russian helicopters and airplanes. Placed all over the aircraft's fuselage, ROFAR elements would continuously supply the crew with a 360-degree integral radar picture, antenna systems working in the active and passive radar modes, all types of electronic countermeasures (ECM), covert and jam-resistant data exchange, communications with the ground and other aircraft and Identification Friend or Foe.

Using new photonics-based materials and componentry, KRET will master advanced production technologies of powerful photo-detectors and semiconductor laser modules.

PROMISING LINES OF EW SYSTEMS DEVELOPMENT

At the 13th sci-tech conference Innovative Electronic Warfare Technologies for Russian Regions, Yuri Mayevsky, KRET's deputy General Director for innovations and R&D of EW systems, delivered a report, named Innovative Technologies for Development and Production of Electronic Warfare Systems.

"At the moment, there are three main groups of technologies for development and production of advanced EW systems," said Mayevsky. "They are applied on all levels of work with advanced EW systems – from making the electronic componentry to manufacturing elements and complete subsystems. This approach facilitates unification and mass production of various civilian and military systems. Within the framework of the new technological platform, KRET is successfully working in all the three areas and has already achieved considerable results."

To date, KRET has virtually created the basis of the Electronic Warfare technological platform, which is within the responsibility of the KRET Electronics directorate (comprehensive supplies of EW systems, measuring equipment, connectors and cables).

The company is implementing the most efficient approach to building EW assets, using a commonised hardware solution and the technology of integrating unified modules. This allows improving an EW system's weight and size characteristics by 30–40%, raising its reliability by 2–3 times, reducing power consumption by 4 times and the cost of works by 4–5 times, as well as cutting development time by 3 times.

An important line of activity for KRET is the development of ultrabroadband antenna systems using the AESA active phased array radar. In the AESA, every element or group of elements has its own miniature microwave transmitter, working in the frequency band from 1 to 18 GHz.

Powerful solid-state amplifiers, made of gallium-arsenide and gallium-nitride technologies, are used as AESA's active elements in modern EW solution. Thanks to them, the equipment's weight can be reduced by 1.5–2 times, raising reliability and efficiency by 2–3 times.

In addition, KRET has launched the manufacture of signal processing modules using the Digital Radio Frequency Memory (DRMF) technology. Within nanoseconds it can produce signals and interferences of virtually any form and process them in the real-time mode.

KRET DEBUTS IN DEFENSE NEWS TOP 100

KRET has made its debut in an international ranking. According to the authoritative US weekly Defense News, the company was ranked 52nd in the list of 100 largest defence companies of the world. In the future, KRET is going not only to strengthen its positions in the arms market, but also energetically diversify its product range heading for the civilian sector.

In the rating, international experts took into account brand recognition, the product's quality and popularity, as well as thoroughly studied the companies' financial results and defence revenue change over several years. Having made significant progress over the last three years, KRET took a worthy place among leading corporations with a long history.

The concern has fulfilled the 2014 state defence order both in terms of volume and schedule. The Russian Defence Ministry received cutting-edge EW and IFF systems, as well as avionics worth a total of 58 billion rubles.

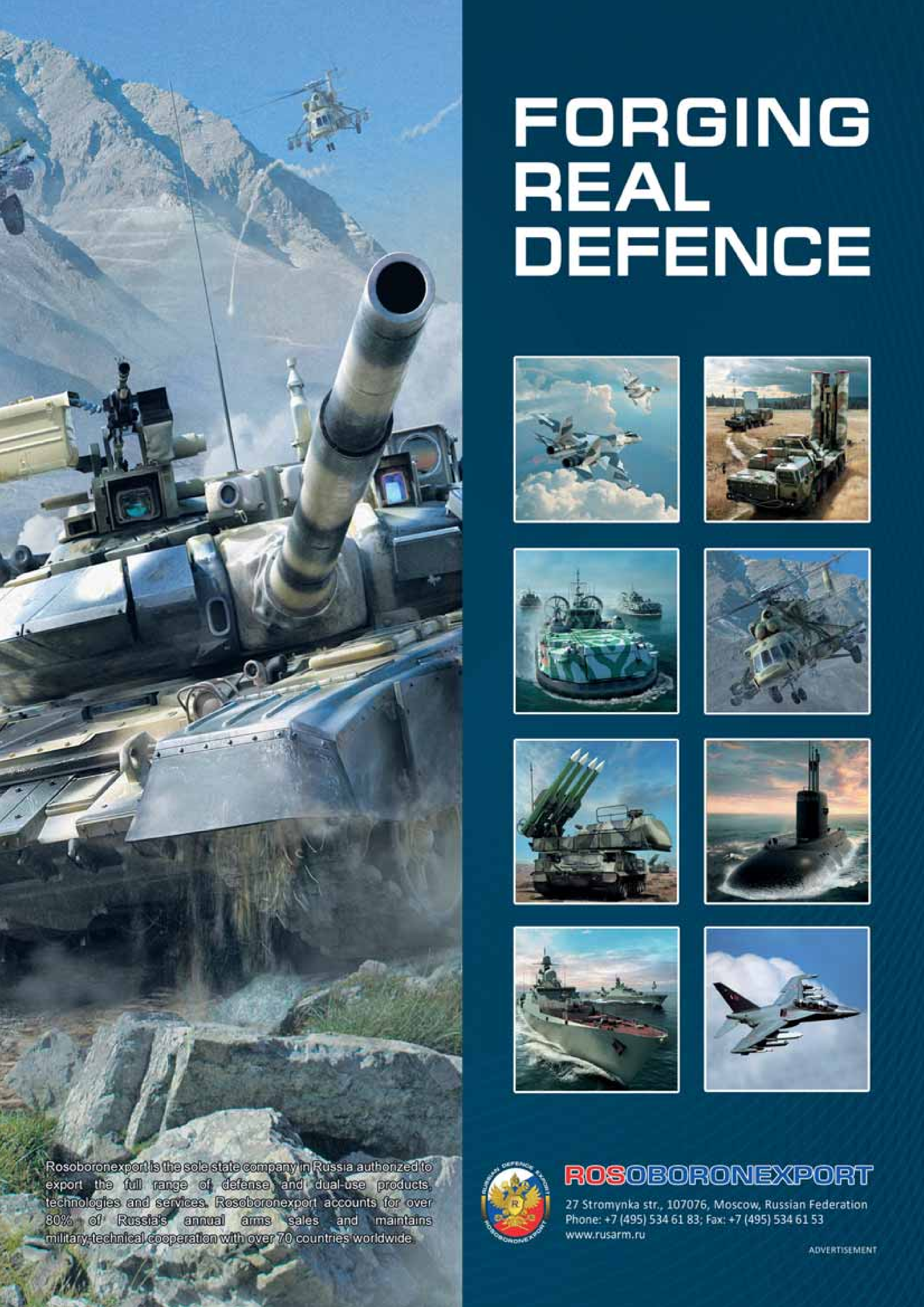
KRET summed up preliminary results of 2014, using Russian accounting standards. The expected total revenue in 2014 amounts to 105 billion rubles, which is 27.7 billion (a third) higher than in 2013. The total net profit amounts to 8 billion rubles, a 1.4 billion increase as compared to the year before.

KRET EXPANDING SCOPE OF ACTIVITY TO DEAL WITH CYBER SECURITY

KRET has introduced a new position of deputy general director for EW information protection technologies. Its first holder became Igor Zhukov, the former deputy general director of the Central Research Institute of Economics, Informatics and Control Systems.

Igor Zhukov is responsible for developing information technologies for identifying cyber threats and protecting civilian and military systems from them. In addition, he supervises the integration of contemporary EW assets and establishment of a new identification friend-or-foe (IFF) system.

"By systemising the works in the field of protected EW information technologies, a diversified holding could be established within Rostec, which would unite under a single brand all areas of modern Russian EW research," said KRET Director General Nikolai Kolesov. "This is just in line with KRET's development strategy, which aims to make the company a comprehensive supplier that offers its customers a full range of special EW solutions."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Russian Defence Industry and Armed Forces

PRESIDENT SUGGESTS NEW COOPERATION FORMS FOR BUYERS OF RUSSIAN ARMS

President Vladimir Putin is sure that Russia is capable of overcoming new challenges in the defence sector and strengthening its positions. Putin called for stepping up cooperation with the traditional and new buyers of Russian armament. "We should energetically work with our traditional partners and new customers," he said at the meeting with the commission for military-technical cooperation with foreign countries.

In 2014 Russian arms makers concluded export contracts worth $7.5 billion, the order backlog remains firmly at around $50 billion. "It is a good result," said Putin.

The president marked that the annual arms export target was surely being met. "To date, foreign customers have received Russian military hardware worth $10 billion," he said, adding that it was over 70 per cent of the overall supplies, planned for 2014.

Putin called to wider use Russia's competitive edge. "It is the major military-industrial potential and Russia's reputation of a reliable partner," said the head of state. "And of course the high demand for Russian weapons is an important factor, too," he said.

According to the president, new cooperation forms should be offered to the buyers of Russian arms, including flexible payments and loans and profound logistics support.

"It is important to use in practice new forms of interaction with the customers of Russian military hardware," said Putin. "I mean flexible settlements and lending and wide logistics support, as well as other modern and effective mechanisms of promoting the products."

The president noted that Russia was ready not only to sell weapons, but also to set up its joint production, repair, improvement and maintenance. "Russia can supply combat-tested mass-produced state-of-the-art systems, which outrun all foreign counterparts in terms of price – quality – efficiency," stressed the Russian leader.

TASS

PRESIDENT SIGNS EXECUTIVE ORDER ESTABLISHING MILITARY-INDUSTRIAL COMMISSION

Vladimir Putin has signed an executive order On the Military-Industrial Commission of the Russian Federation.

The executive order aims to implement state policy in the defence industry and ensure military-technical support to the country's defence, security and law enforcement activities.

Russian President's website

PRESIDENT'S INSTRUCTIONS BEING IMPLEMENTED

Supreme Commander-in-Chief Vladimir Putin has approved the decisions that would allow keeping up with the schedules of arms development, production and supplies for the Armed Forces, said Defence Minister Sergei Shoigu.

"From 24 to 28 November 2014, Russian President Vladimir Putin held meetings in Sochi with Defence Ministry officials and representatives of defence companies. They worked out measures to avoid delays in equipping the troops with advanced military hardware and carrying out their maintenance and repair," he said.

According to defence minister, the participants of the Sochi meetings also discussed the issues of military infrastructure buildup in the Arctic and approved the steps to be made to ensure decent living conditions of the troops, deployed in the polar regions.

In addition, Shoigu noted that all the instructions given by the supreme commander-in-chief in Sochi are already being implemented. Relevant amendments to the Defence Ministry's action plan until 2020 will be made.

TASS

RUSSIAN PRESIDENT APPROVES NEW EDITION OF MILITARY DOCTRINE

"A clarification has been introduced in the Russian Federation Military Doctrine to comply with the Resolution of the Security Council of Russia of 5 July 2013. The amendments were approved by the Security Council on 19 December 2014," reads a report, published on the Russian President's website on 26 December 2014.

The doctrine lists among major foreign military threats to Russia the deployment of strategic missile defence systems, implementation of the US Prompt Global Strike concept, intention to deploy strategic weapons in space and deployment of strategic conventional precision weapons. In addition, the doctrine outlines as major threats the military buildup of NATO, which is taking upon itself "global functions implemented in defiance of international law", as well as military infrastructure of the NATO member states getting close to the Russian borders.

Another foreign military threat consists in the territorial claims on Russia and its allies and interference in their internal affairs, as well as "the use of military force in the countries bordering on Russia and its allies in violation of the UN Charter and other rules of international law".

One of the key internal military 'dangers', as stipulated in the document, is the information influence on the population, primarily, young people, which aims to undermine their historic, spiritual and patriotic traditions of defending the Motherland. The doctrine marks a shift of military dangers and threats to the information space and internal affairs of Russia.

The doctrine's new edition introduces the notion of 'non-nuclear deterrence', which means maintaining general-purpose forces on high alert.

Defence of Russia' national interests in the Arctic has been included in the Armed Forces' key tasks. The doctrine also reflects wider cooperation with the BRICS members and closer ties with Abkhazia and South Ossetia.

Written using the materials from the Russian President's website

RUSSIA FINALISES MI-17V-5 SUPPLIES TO AFGHANISTAN

In October 2014, Russia completed its deliveries of Mi-17V-5 military transport helicopters to the Afghan National Army. A total of 63 helicopters have been supplied to Afghanistan under the 2011 deal between Rosoboronexport and the US Department of the Army. The aircraft were manufactured by the Kazan Helicopters (a division of the Russian Helicopters holding).

Rosoboronexport has gained a reputation of a reliable supplier of these helicopters, and the contract's implementation was highly estimated by the American partners. Mi-17 helicopters perform well in adverse climate and mountainous terrain. The delivery contributes to the establishment of the Afghan National Security Forces and is part of Russian and US efforts to fight international terrorism.

On behalf of the Russian side, the Federal Service for Military-Technical Cooperation confirms its readiness to discuss further deliveries of Mil-type helicopters, as well as maintenance of the Russian helicopters that are already being operated.

Press release by FSMTC

RUSSIAN NAVY TO BUILD UP GLOBAL PRESENCE

In 2015 the Russian Navy is aiming to build up its presence in the world ocean, Russian Defense Ministry spokesman Captain 1st Rank Igor Dygalo told Interfax-AVN.

"Over fifty warships and supply vessels are now on missions in different parts of the world ocean, in groups and by themselves. The intensity of the Navy's training will increase in 2015," said Dygalo.

He noted that the Russian Navy will work on "guaranteeing the security and stability in seas and oceans."

Interfax – Military News Agency

KA-226T HELICOPTER TO BE CERTIFIED

The Ka-226T seven-seat light utility helicopter, powered by the French-made Turbomeca Arrius 2G engine, is to be certified in the first quarter of 2015, Interfax-AVN learnt from a source in the Russian aircraft industry.

"The Ka-226T helicopter has virtually completed certification tests. The certificate may be obtained in the first quarter," said the source, noting that "some easy to tackle issues remain", primarily concerning the paper work.

"Two Ka-226Ts were used for the certification tests, while at least five helicopters of this modification have been built.

The aircraft is powered by two 670-hp Turbomeca Arrius 2G gas-turbine engines, featuring high altitude, top-notch reliability and long service life.

Interfax – Military News Agency

RUSSIAN AIR FORCE TO INTRODUCE EXPERIENCE OF ITS INDIAN COUNTERPART

Russia will analyse the aircraft's performance at the Aviaindra 2014 international drills and introduce the Indian Air Force's experience in the training practice of its own military aviation, said Russian Defence Ministry spokesman Col. Igor Klimov.

"The experience of Russian-made aircraft's operation and maintenance and the positive sides of flight training in the Indian Air Force will be analysed and implemented by the Russian Air Force," said Klimov.

From 17 to 28 November 2014, India hosted the second phase of the Aviaindra 2014 joint Russian-Indian exercise. The first phase was held from 25 August to 5 September 2014. The aim of the exercise was to train combined flight crews to carry out different missions.

Earlier in 2014, Russia and India had conducted joint naval manoeuvres, named Indra 2014.

RIA Novosti

STRENGTHENING SPACE TRACKING CAPABILITY

The Russian space tracking system will in the next few years be augmented by more than 10 new-generation stations, said Commander of the Aerospace Defense Forces (ADF) Lt. Gen. Alexander Golovko.

"In 2014, ADF started deploying a network of specialised ground-based laser-optical and ELINT space object recognition systems, which make it possible to substantially enhance the information capabilities of the Russian space tracking system, expand the range of monitored orbits and cut half or threefold the minimum size of space objects that can be detected," he said.

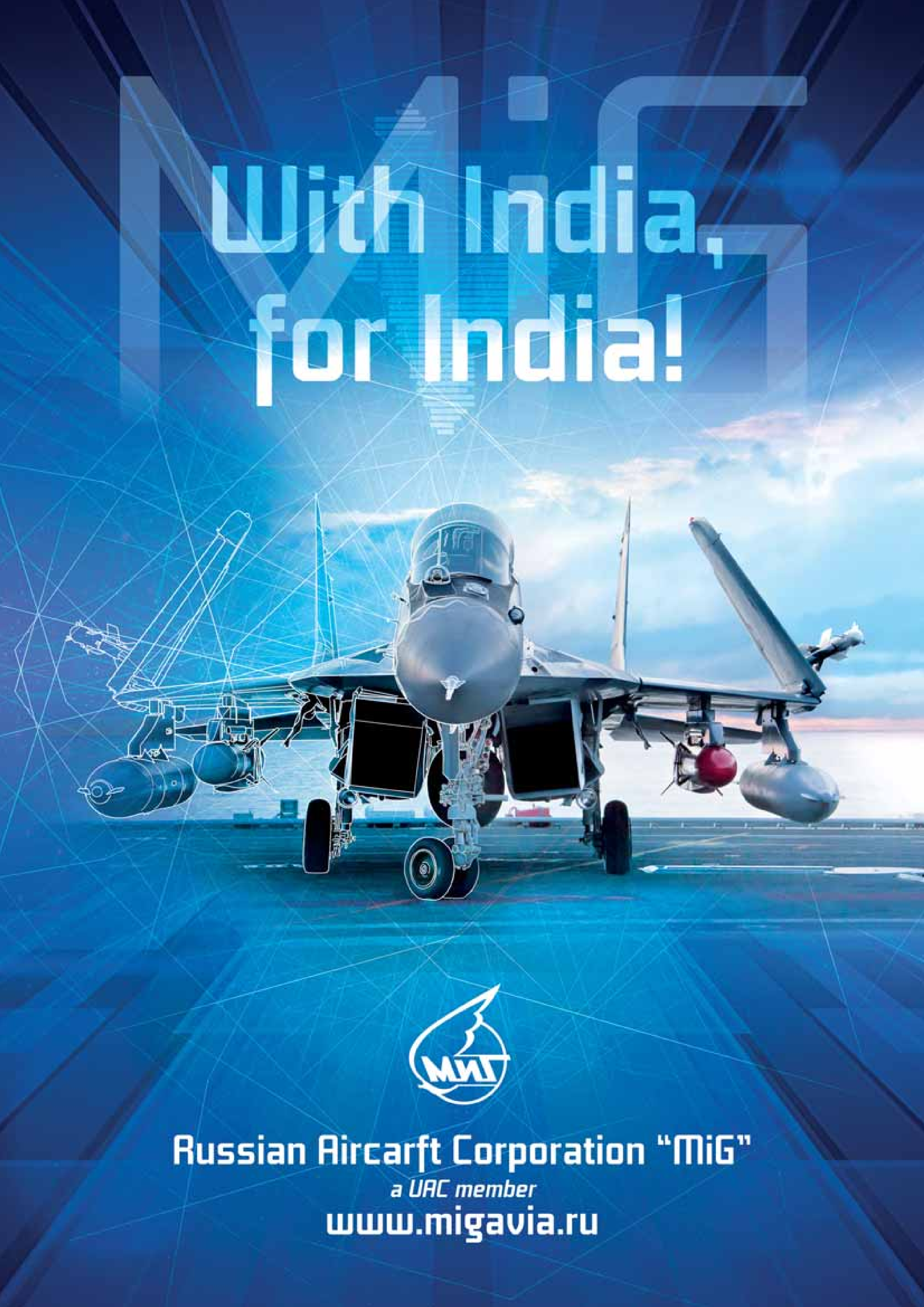
According to Golovko, the first new-generation system, manufactured in Russia's Altai Territory, has successfully passed the state trials. "A total of 10+ new-generation space tracking stations will be deployed in some Russian regions," he added.

In addition, the upgraded Okno-M optical-electronic space surveillance system has completed the state tests.

"Under the Okno programme, four more new optical-electronic space object identification and tracking stations have entered the inventory, they have been equipped with advanced TV identification systems and new-generation computers, developed using indigenous element base," said Alexander Golovko.

According to Golovko, the stations would enable ADF to monitor all the orbits used by spacecraft. The Okno's identification capability and performance, as well as the data processing capability have risen by several times. At the moment, the Okno station is getting ready to enter service with the ADF Command's Main Space Surveillance Centre, where it would be put on combat duty.

TASS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Together for half a century

NIKOLAI VALUEV
Radio Electronic Technology magazine
Managing editor

Over half a century ago, the first Russian-built warplane entered service with the Indian Air Force (IAF). It was the then-cutting-edge MiG-21 supersonic fighter. The daring decision on launching military-technical cooperation with Moscow, taken by Indian leaders early in the '60, proved right and truly crucial. MiG fighters performed great in the armed conflicts in the Hindustan Peninsula and became a formidable deterrent of aggression and an effective means of stability in the south of Asia.

Essentially, the record of MiG fighters in service with IAF is mirroring the evolution of the relations between the two great powers. The Soviet Union succeeded by Russia has always provided India with its latest high-tech products – both commercial and military ones. Suffice it to say that India was the first foreign customer for the MiG-29 fighter in the '80s.

It is nice that the Indian-Russian military-technical cooperation has never been marred with either political or technical problems.

It is important, too, that from the very outset, Russia has not only supplied planes, but also has exercised large-scale technology transfer, thus facilitating the quality development of India's industry and defensive capabilities. For instance, the MiG-21 and MiG-27 were licence-produced by HAL and had for a long time made up the mainstay of the tactical aircraft fleet of our great southern partner. Today, Indian industry has shouldered the lion's share of the MiG-29 upgrade work. In line with the letter and spirit of the latest Russian-Indian governmental agreements, the MiG corporation has been proactive in pursuing offset programmes under current contracts. On the other hand, the Indian military contributed heavily to the evolution of the views and competencies of Russian designers in the course of the MiG-21 and MiG-23 upgrade.

The joint work of Russian and Indian engineers under the MiG-29K/KUB carrier-borne fighter programme has embodied innovative approaches. Under the programme, Indian companies and organisations act as full-fledged participants in all of the phases of the products' life cycle. Indian naval aviators have contributed much to the finalisation of the fighter's configuration, while engineers with HAL and other Indian firms have designed and been manufacturing a number of key components of the MiG-29K/KUB.

The single-seat MiG-29K and two-seat MiG-29KUB are Generation 4++ multirole fighters designed for air defence to naval task forces, air superiority and elimination of surface threats with precision-guided weapons round the clock in all weather.

The MiG-29K/KUB carrierborne fighters are the baseline models of the new commonised family also including the MiG-29M/M2, MiG-35 and MiG-35D.

MiG-21bis Bison

The MiG-29K/KUB fighters are designed to be based on aircraft carriers, displacing at least 28,000 t and fitted with a takeoff ramp and arrestor gear, and on land-based airfield as well.

As other aircraft of the commonised family, the feature improved operating characteristics and enhanced reliability of units and systems. Compared with the earlier produced fighters, the MiG-29K/KUB's service life has more than doubled, while the cost of their flying hour has dropped by almost 2.5 times. The MiG-29K/KUB fighters do not require overhaul.

The job done by MiG Corp. in the later 2000s has resulted in a Gen. 4++ combat aircraft entering service now and being as good as any latest carrierborne fighter in the world.

These days, the MiG-29K/KUB fighters operate off Indian aircraft carrier Vikramaditya, while MiG Corp. is delivering a second major batch of the aircraft of the type to India. The Russian variants of the MiG-29K/KUB are entering the inventory of the Russian Navy's air branch.

MiG Corp. also has much assisted in training Indian naval aviators, who had to learn to operate from an aircraft carrier, which is no cakewalk. Having seen the results produced by the Indian naval pilots in the course of the training, MiG Corp. Director General Sergei Korotkov said: "We were impressed with the professionalism of the Indian pilots, who, assisted by MiG Corp. test pilots, quickly mastered MiG-29K/KUB operations off the Vikramaditya aircraft carrier".

The success of the shipborne fighter enabled MiG Corp. to develop what essentially is a new family of land-based fighters, comprising the MiG-29M/M2 and MiG-35. The MiG-29M/M2 multirole fighters have entered full-rate production, while the MiG-35, which avionics and other equipment include fifth-generation components, is undergoing the last flight tests and modifications in the run-up to deliveries to the Russian Air Force (RusAF) and foreign buyers. According to estimates of the Russian Defence Ministry that included the MiG-35 into the long-term armament acquisition programme, about 100 aircraft of the type are slated for production.

At the same time, RusAF continues its MiG-29SMT multirole fighter acquisition after the type has proven itself. Another contract for 16-ship MiG-29SMT batch was landed by MiG Corp. in April 2014 and shall have been fulfilled within two years. The MiG-29SMT's strengths include an outstanding combination of high effectiveness and a relatively low cost. In addition, the fighter is just the thing for customers possessing the infrastructure for and experience of operating earlier MiG-29 variants.

A MiG-29KUB at the trials on deck of the INS Vikramaditya

The MiG-29SMT is comparable to the MiG-29UPG as far as their capabilities are concerned. The MiG-29UPG, an upgraded version of the classic MiG-29, is entering IAF's inventory now. The first aircraft of the type have been overhauled and upgraded in Russia. The rest of the fighter fleet will be upgraded to MiG-29UPG standard by Indian companies assisted by Russian engineers. The knockdown kits required for the upgrade have been delivered to India.

An important event has been the improvement in the MiG-29 operation support system in India. For instance, a service centre for integrated servicing of various versions of MiG fighters is to be opened in India in 2015.

Offset programmes are evolving to support the operation of MiG aircraft and provide assistance to India's high-tech industry.

India remains the top foreign partner of MiG Corp., and the corporation is ready to pursue and step up the cooperation in a new form.

In December 2014, MiG Corp. marked a jubilee – the 75th anniversary of the design bureau named after Artyom Mikoyan. MiG Corp. has gone hand in hand with India for over 50 years – two-thirds of the time that has passed since its inception.

Radars with Electronic Beam Control for Combat Air Force

YURY BELY
Director General,
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ANATOLY SINANI
Deputy Director General for Scientific Research,
Chief Designer,
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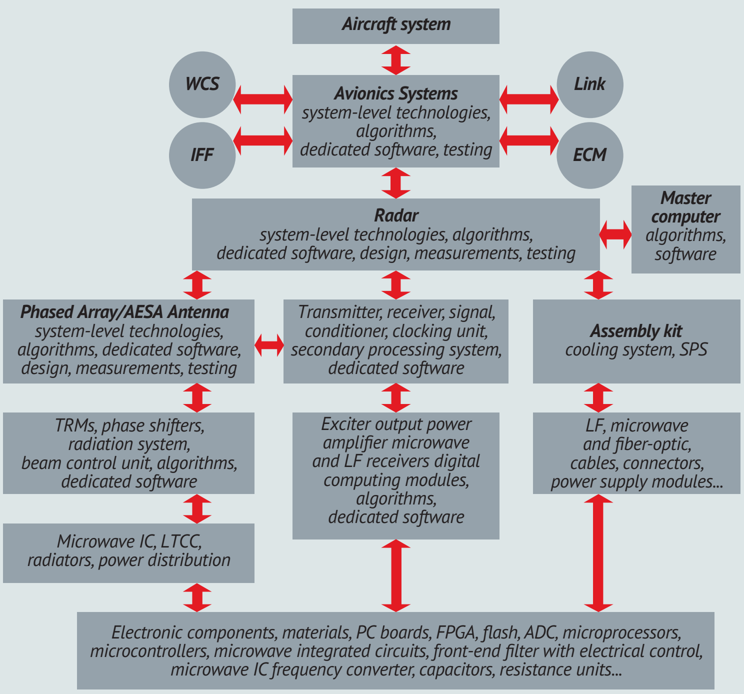
Radar targeting systems constitute the basis of modern aircraft avionics systems. This special role of the radar is getting stronger over time, which is due, primarily, to material increase in complexity of tactical, technical and combat tasks and resulting fast development of microwave technologies and computing systems, and secondly, to optimal environment for integration with other airborne systems, including electronic intelligence and ECM, IFF, directional links, etc. A simplified functional diagram showing the avionics system and its relation to other technologies is shown in Fig. 1.

In this functional diagram, we have tried to reflect the complexity of mutual coupling between components as well as rather strict structuring of the avionics system.

Fig. 1. Avionics technology synthesis



Almost 50 years ago, electronic beam control was selected by our Institute as a basis for airborne radar design. Therefore, the left column in Fig. 1 shows only antenna versions with electronic beam control.

The first avionics product based on this concept was the Zaslon weapon control system created in 1980 for the MiG-31 fighter.

Our concept has been applied in designs over the recent decade and has proven to be viable for the aviation industry.

The most illustrative design of our Institute within this period in terms of radars with passive phased arrays is the Irbis radar control system for Su-35 (Fig. 2), and as for radars with active phased arrays (AESA) a good example is the radar which is being created for the PMF together with the Indian party (Fig. 3).

The Irbis radar has an antenna system with a passive phased array, which is installed on a double-step drive. If compared to previous radar generations, the scanned area has been expanded more than twice, up to 240°. The power performance arrives at $P \cdot G \approx 5.5 \cdot 10^7$ (where P – radiated power, G – antenna gain), and the target detection range is at least 400 km for targets with $\sigma = 3 m^2$. This has been achieved due to excellent antenna properties ($G/4\pi s/\lambda^2$ being over 0.55) as well as high power value of the transmitter ($P_{aver} = 5$ kW).

Electro-dynamic performance of passive phased arrays has increased alongside with the reduction of weight and dimensions, which has made it possible to install the antenna upon an electro-hydraulic drive and obtain a record-setting surveillance zone for the radar.

The aggregate effect was mostly a result of innovative technical solutions applied across all functional systems of the phased array. In the waveguide power distribution system, a new

Left – SuperSkat phased array for Irbis radar control system (Fig. 2)

Right – X-band AESA designed by NIIP JSC (Fig. 3)

compact plank structure was applied, and wide-band couplers were designed, which allowed for material enhancement of the operating frequency band while maintaining a high efficiency rate. The phasing system has been improved thanks to using a ferrite phase shifter. This allowed to improve the antenna bandness response and electronic control performance, which made it possible to reduce errors when setting controllable phase distribution within the aperture δ≤4°÷5°. Significant progress has been made in terms of design and processes. The antenna unit weight calculated via dividing the total weight by the number of elements has been brought down by ~15%. The evolution of passive phased arrays designed by our Institute has successfully passed inspection at the commercial production plant in Ryazan GRPZ JSC, which became engaged in at the pilot sample production stage and then passed to commercial delivery of Irbis radars for Su-35 fighters.

Design and commercial delivery of radars with active phased arrays is a more challenging task for our Institute and the Ryazan plant.

The avionics system for the PMF is based on three active phased arrays: one forward looking (FL) phased array, and two side-looking ones (to the right and to the left respectively). The aggregate scanned area is almost 300° (Fig. 4).

Both design schemes – the flexible driven antenna and a set of fixed antennas – have a right for existence. The only difference lies in the ability to support this or that instantaneous scanned sector.

Please note a rather high value of the power performance P•G (Fig. 5). It can be observed that each subsequent AESA has shown a higher P•G value as a result of more effective operating mode trials and better manufacturing process. Let us also point out that the AESA component base and submodules remained the same.

Fig. 4. Example of the estimate area scanned by three fixed active phased arrays, X-band

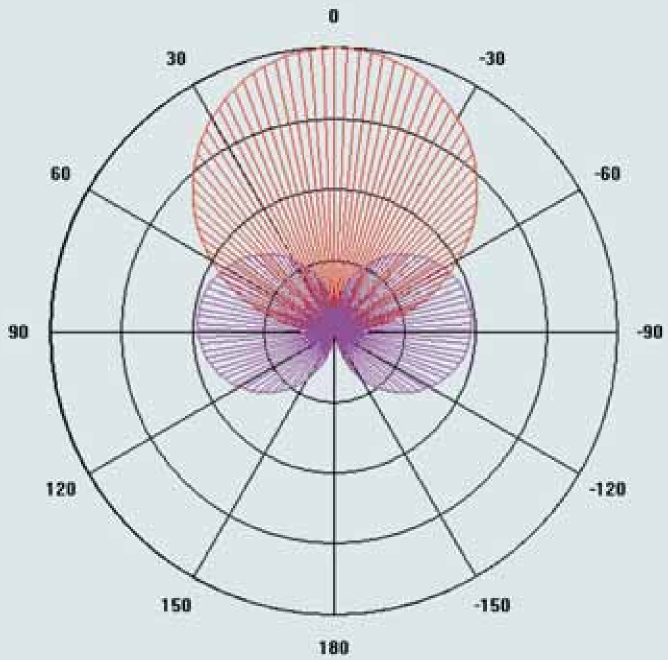
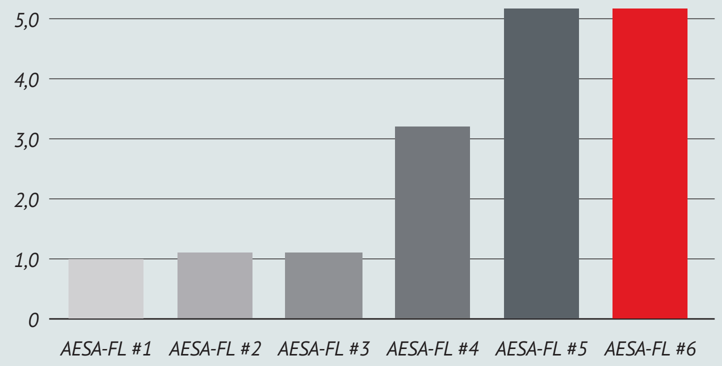


Fig. 5. Relative increase in the AESA radar performance



At the stage of first AESA pilot designs, an important segment of work was related to implementation of new operation modes. In particular, we worked on the procedure of managing the antenna gain and sidelobe level depending on the radar operation mode. Further review of possibilities to implement new modes is still underway. This process implies deeper understanding of the electronic beam control capabilities, dealing with new radar-related challenges resulting from the need to enhance jamming resistance and resolution in air-to-surface modes, as well as upgrade of existing technologies.

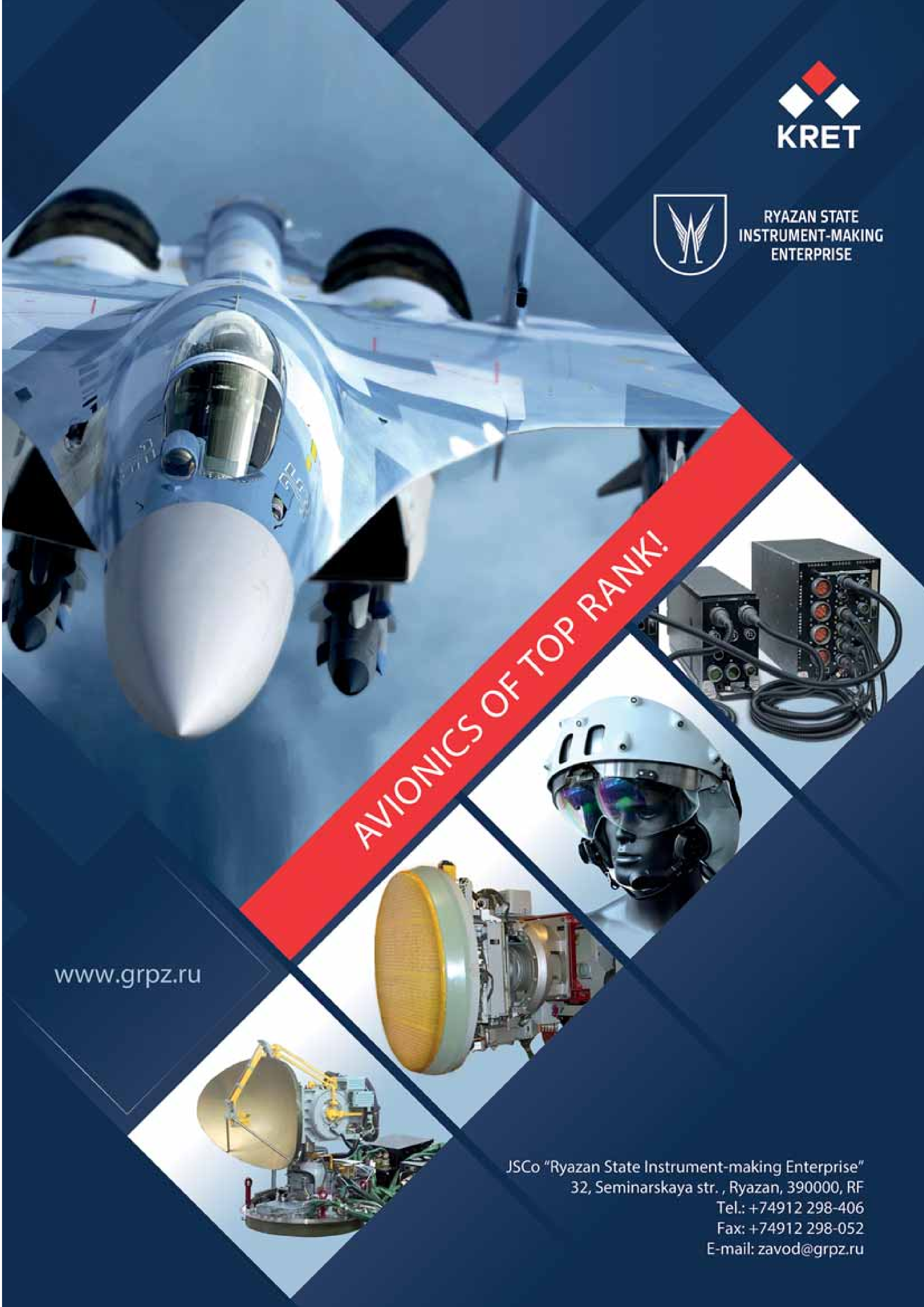
Fig. 6. BARS radar for the Su-30MKI fighter

From a long-term standpoint, we deem it necessary to enhance integration of aircraft avionics equipment via development of its core, i.e. the radar. So we take the scheme presented in Fig. 1 as a design basis as it has proven viable within the period of over 30 years of operation.

Let us point out that both solutions are aimed at solving tasks related to jamming resistance and resolution capacity enhancement via introducing new probing signals and processing algorithms, as well as Rx beamforming, development of modes ensuring avionics equipment integration, reduction of angular errors, including by means of the antenna-radome system optimization, use of 3D technology, increase of photonics equipment share in beam control circuits, etc. Radars with passive phased arrays will face such challenges as creation of solid-state microwave output power amplifiers instead of vacuum units and enhancement of operational reliability. For AESA radars the key challenge is cost reduction.

The viability of our short-term and long-term programs is governed by the progress made by our scientific and engineering pool capable of handling all tasks related to analysis and synthesis of system-level and specific areas of airborne radar development, upgrade of technologies which would fit the respective historical stage as well as close cooperation with colleagues across all relevant sectors – from the component base to the aircraft level.

In conclusion, it is worth stressing the important role of cooperation between our Institute and the Indian colleagues in terms of airborne radar development. The design of BARS radar for Su-30MKI fighters (Fig. 6), which started in the late 1990s, is an illustrative and instructive example of joint work carried out by specialists of our two countries. One can surely expect that in the future together we will be able to handle new technological and fundamental challenges related to further generations of radar systems with electronic beam control for the aviation industry, and, most probably, for other areas of radar technology application.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Phazotron-NIIR
Corporation JSC

Every country follows its own way in radar development. The results produced by all countries are the same. The truth opens gradually, as mankind becomes more knowledgeable. An indisputable fact testifies to it: all discoveries were made in various corners of the world virtually simultaneously. I had deemed it strange before I started making discoveries myself.

A few examples are due. There was the time when the world used Cassegrain antennas – the Americans, British, Germans, French and us, Russians. Cassegrain antennas then we ditched for slotted-array radars. That was a new stage in the radar development in the world. A slotted array antenna in a radar was a plane's pass to international air shows.

First, designers offered three antenna variants – printed, dipole and slotted. The theoretical basis of the latter is simple, calling for fundamental development at the same time. I am grateful to Moscow Aviation Institute Professor Vassily A. Kritsyn, who taught us, students, the slotted array antenna theory and physics so clearly that I still remember his lectures on slotted array antenna design. When I scrapped up a bit of spare time and my hands were untied, I ran a development work on all three variants. The former two proved imperfect, thus leaving the slotted-array antenna. By trial and error, we arrived at the conclusion that film should be stuck on the array. Film would keep on coming unstuck. We needed to select a film and a glue to create the 01-atm pressure inside. The 'epopee' had lasted until process engineers at a conference finally came up with a solution how to stick the film on. Many said at the time, like, you stole the technologies from the Americans. Nothing of the kind. The Americans had come up with the same solution just a bit before us. They seem to have just bought a patent for the technology in Europe. It is the British who were the Europeans to develop the slotted-array antenna and the French were the last.

I happened to visit the Marconi company in Edinburgh, a slotted-array antenna manufacturer. At the time, direct-drive torque motors were used. "We've got the same", noted I with surprise and, knowing full well the motor's weakness, stretched out my arm and stopped it. Just like ours, the British motor lacked torque to cast off my arm. Naturally, everybody was surprised at the similarity of our problems and our achievements in technology. By the way, you will be unable to stop a motor with your hand.

Our slotted-array antenna had numerous solutions of our own. At the time, our antenna was among the best in the world, even better than the one the Americans had. When we unveiled the Zhuk slotted-array antenna radar to the air show in Paris in 1992, the French were very keen on it. French engineers and we were exchanging views, inter alia, on US radar development. The Americans had a simple approach: the pilot would throw switches, thus fulfilling the program. They even boasted that the control stick had so many buttons that the pilot had to have the fingers of a piano man to control the radar. Our approach was more akin to artificial intellect. Our radar does its job on its own, with the pilot just supervising it. It is an unobtrusive artificial intellect optimising the radar's operation continuously. We had a long talk with French engineers. They said they were close to the conclusion that it was time to introduce automation while the US approach was imperfect.

Now, our radars equip MiG-29 fighters in service with many an air force worldwide. Several variants of the Zhuk-ME slotted-array radar are in full-rate production. The radars of the type fit the advanced MIG-29SMT, MiG-29K/KUB and MiG-29M/M2 as well as the Indian Air Force MiG-29UPGs being modernised now.

Progress does not stand still, however. I realised that the Zhuk was in need of an active electronically-scanned array (AESA); therefore, we switched from the slotted-array antenna radar to the development of radars based on passive and active phased arrays. Our Western 'friends' often maintain the Soviet

Union allegedly copied the antennas from Western examples, adding little of its own. However, each of the nations followed its own way of developing passive and active phased arrays.

ACTIVE PHASED ARRAYS FOR FIGHTERS

To develop an AESA, Phazotron-NIIR got engineers from the Altair maritime radio electronics research institute involved in the programme. Part of the bench tests of the demonstration variant of the advanced radar – the FGA-29 with an AESA 500 mm in diameter – were conducted in 2006. Early in 2007, the demo version was mounted on the MiG-35 technology demonstrator (side number 154) and displayed at the Aero India 2007 air show in Bengaluru. Foreign customers were delighted with our radar, for they had not seen anything like that anywhere, including the United States. I realised later that foreign designers had used our array development principle in their own work.

In April 2010, our radar passed its flight trials, involving both Russian and Indian military pilots, as part of a MiG-35D plane designed for delivery to India. The Indian pilots tested it, launched a missile and hit the target. Then… Russia had forgotten about AESA radars for five years and has just recalled that the whole world is making AESA radar-equipped fighters while we have it fitting only the Sukhoi T-50 fifth generation tactical fighter in a variant leaving its designers much for improvement.

Electronics professionals all over the world have scrutinised articles on our designs, published in trade journals, and their first question was: "How do you replace twin T-R modules? By removing four at once?" I told them we had a bit different technology, and the foreign engineers were truly sorry for us, like, you guys should have developed a T-R module similar to that used by the AESA with flat T-R modules reliant on the 3D technology. I have seen more interest particularly in our version on the part of potential Indian and Chinese customers.

To equip the production-standard fighters of the MiG-29/MiG-35 family, we have developed a Zhuk-AE radar variant with an AESA diameter increased up to 688 mm – the FGA-35. The number of T-R modules in the array has grown by almost 50% to more than 1,000. The radar's performance has improved much with a negligible increase in weight.

...AND HELICOPTERS

The Ka-27M upgraded for the Russian Navy completed its tests in late 2014. Its organic Osminog surveillance and targeting system was replaced with the advanced Phazotron-NIIR Kopyo-AA command tactical radar system. The advanced radar was given the air-to-air mode. The airborne radar provides full situational awareness and even sees planes flying at an altitude of up to 2,000 m. Nevertheless, the modernised Ka-27's basic function is to spot submarines at periscope depth and feed the data to shipborne and land-based command posts. The helicopter is able to seal off the submarine search area independently by dropping sonobuoys and then engage the target(s) with depth charges and torpedoes. Under the upgrade programme, Phazotron-NIIR was dual-hated as both developer of the sophisticated radar and integrator of the whole of the tactical radar system, supplying a digital computer and a navigation display. The overhauled and upgraded Ka-27Ms furnished with our radar system will have been able to remain in service with the Russian Navy for another 10–15 years.

The Ka-27 upgrade programme is not the only helicopter-related programme pursued by Phazotron-NIIR. The corporation also is the developer and manufacturer of the Arbalet millimetre-wave radar designed to fit the Ka-52 attack helicopter in the Russian Air Force's inventory.

The Arbalet's developed to equip the Ka-52 kicked off as far back as the mid-1990s. It was a

Zhuk-AE (FGA-29) AESA radar onboard MiG-35D technology demonstrator very hard time for both the corporation and defence industry as a whole. The defence spending was next to nothing. Nonetheless, we decided to make an export version of the radar. In 1997, we launched its flight tests on a Ka-52 prototype. The tests had lasted until 2002, when normal funding of the programme under the governmental defence acquisition programme started at long last. This allowed the resumption of the work on the baseline model of the radar known as FH01 now.

We had conducted the time-consuming tests of the advanced radar, including bench, acceptance, joint services, flight and, finally, official trials that were complete in 2011. The new radar system entered full-rate production, and combat units continue to be fielded with it. Many RusAF units operate the Ka-52 helicopters carrying our radars now.

We have developed a dual-band radar to equip the shipborne variant of the helicopter. Its centimetre band with a range of 200 km will allow using weapons against ships, while its millimetre band can be used for engaging land-based targets. The Russian military has not confirmed its interest in the programme yet. Probably, the solution is in the international aspect and depends on the delivery of the Mistral-class amphibious assault ships, for which the Russian Defence Ministry planned to order a batch of Ka-52K shipborne helicopters derived from the land-based Ka-52. If France meets its contractual obligations, we would like to fit our latest radar to the Ka-52's shipborne variant as well.

RADARS FOR NAVY AND TANKS

Phazotron-NIIR has made progress in developing radars for surface ships as well. Speaking of a ship's superstructure, it has three to four radars operating in their own frequency ranges – decimetre, centimetre, millimetre and metre ones. There is a simple explanation for this – the longer the wavelength, the higher is the surveillance speed and, hence, the better is target acquisition around the ship. Radars operating in the metric band are best fit for this purpose. However, the next problem is target classification and accurate guidance of weapons. For this purpose, one needs radars using other wavebands complaint with the characteristics of weapons used.

For instance, the Kortik close-range air defence gun/missile system is fully automatic in the radio-frequency and TV/optical modes in terms of battle management from target acquisition to engagement. It has a total rate of fire of 10,000 rd./min. An incoming antiship missile flying at low altitude shows up 10 km away from the ship. We need to spot it quickly, lay the weapons fast and engage it rapidly or set up a cloud of passive countermeasures to disrupt its guidance at a distance of 1.5–8 km away. Therefore, while the present-day set of our radars offers a guidance accuracy of 3 deg. of arc, improvements to this capability call for the availability of a millimetre, centimetre or optical channel capable of target designation of the 1–2 angular minute accuracy. In the final analysis, an integrated system is required, embodying different radar channels mated with the optronic system.

A separate very interesting subject is protection of army armoured vehicles from antitank weapons using grazing or diving trajectories. In this field, the speed of intercept of top-attack and, possibly further down the road, armour-piercing fin-stabilised discarding-sabot projectiles is important too.

3D TECHNOLOGIES

Further improvement in airborne radars and development of new-generation of such radars has a tendency towards the development of digital radars and digital integrated AESAs based on 3D technologies. Their manufacture may involve not only low-temperature co-fired ceramic (LTCC), but other materials as well.

ED technologies allow T-R module microcircuits to be placed one upon another in layers, rather on a flat board as before. Resultant modules are smaller, lighter and more reliable. Their service life is comparable to that of the aircraft they equip.

In 2013, we designed an advanced AESA with cutting-edge dual-band T-R modules based on the 3D technology. The Semiconductor Instrument Research Institute (NIIPP) in the city of Tomsk is developing the modules. A demo mock-up of the radar furnished with the latest AESA was unveiled at the MAKS 2013 air show in Zhukovsky, Moscow Region.

The T-R module feature is its emitters being dual-hatted as its top cover. To provide the radio-frequency characteristics required, the emitter is based on the 12-layer LTCC 3D technology allowing both the manufacture of the layered board with its T-R module elements and the growing of the ceramic casing around it, with the board becoming part of the casing.

An antenna manufactured using the 3D technology is a next step in radar development. We are proud of the fact that Russia pioneered the technology, having gotten ahead of its competition – the UK, Germany, the US and France.

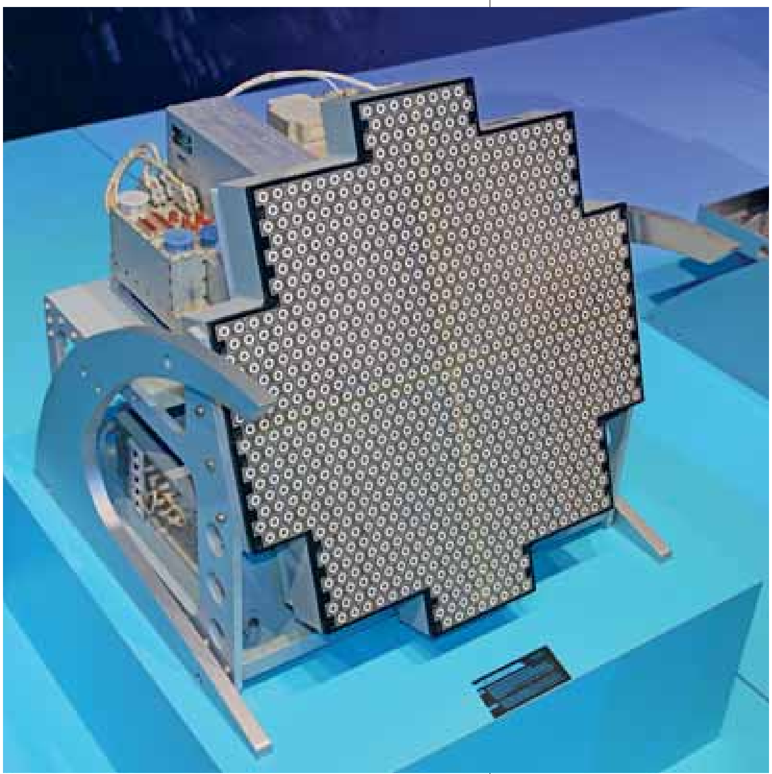
We have completed preliminary tests of the advanced T-R modules, proving the required characteristics in the X-band. We have gotten an output signal with a pulsed power exceeding 5W. The dimensions of the 3D dual-band module are within 12x34x10 mm and its weight is merely 16 g. I hope we will soon be able to manufacture the first experimental airborne radar with the AESA based on these modules and to launch its trials first in our labs and then on board an aircraft. I am certain that airborne radars like that own the future.

The first platform for our latest radar will most likely be an advanced Russian-built unmanned aerial vehicle (UAV). We believe the radar designed for a heavy UAV will be able to scan airspace with the 200-km radius. A medium UAV will need a synthetic aperture radar with the 30–50-cm resolution in the ground mapping mode round the clock at any weather. Some of the data gathered will be processed on board and the other will be fed to ground-based command posts.

THIN FILM OWNS THE FUTURE

The next step past the 3D technology is a film technology with the use of radio-photon optics that will allow an improvement in the efficiency of electronic equipment by tens of times. In the near future, we are going to transition to the AESA design film technology that is based on nano-optoelectronics and allows full implementation of the aircraft 'smart skin' concept. Nano-optoelectronics in radio-optical AESAs will enable airborne radars to handle ultra-wideband signals, while the additional use of digital circuitry will turn the AESA into a multifunction antenna system for the airborne radar as a whole.

Bright vistas in electronics are offered by graphene, the 2D allotropic version of carbon made up of a carbon-atom layer one atom thick. A film only 4 mm thick will oust equipment that is cumbersome in terms of future measurements. Organic film-based nano-optoelectronics will ensure considerable freedom of spatial positioning of emitters on the surface of the carrier of the radio-optical AESA. Thus, the concept of the smart skin of an aircraft fuselage



Phazotron's advanced AESA radar

will be implemented. We see the way towards the smart skin and we know how it can be made.

The most interesting thing is to see in 2014 what will take place in 2020. When I was young, I was lucky to participate in all programmes pursued by Phazotron-NIIR then and operate in support of them until a product's service entry. Over 50 years plus, the Phazotron-NIIR Corporation has developed several generations of airborne radar systems fit with various types of antennas to equip dedicated and multirole aircraft. The corporation has gained a wealth of expertise in designing complex radio electronic systems, with the expertise being worth sharing and compared with foreign advances in radars. If I retire one day, I will heartily give a detailed description of all radars made in this country and abroad since the advent of radar, for this information is a heritage of global scientific and technological progress.

Road to success

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The Ulyanovsk Instrument Manufacturing Design Bureau (UIMDB), a subsidiary of the Concern Radio-electronic technologies (itself a subsidiary of the Rostec Corporation) is among Russia's oldest developers and manufacturers of aircraft equipment and general industrial equipment.

At present, every Russian-made fixed-wing and rotary-wing aircraft is fitted with avionics developed and made in the city of Ulyanovsk. Gaining new competencies, the company has progressed from developing sensors and 'steam-gauge'-type instruments to developing and supplying integrated flight navigation systems.

In 2014, the Utyos factory merged with UIMDB, which resulted in a major scientific and production entity in Ulyanovsk. Against the backdrop of ever stiffer competition, synergy resultant from the merger will enable the company to retain its leadership on the avionics development and production market.

UIMDB is a developer and manufacturer of avionics for such combat and commercial planes as the Yak-130, Su-27SM, Su-30MK, Su-34, Su-35, T-50, MiG-29, Sukhoi Superjet 100, Be-200, Il-96-300, Il-114, Il-76MF, An-148, An-158, Tu-204, Tu-214, etc. The company develops electronic display and warning systems, critical conditions warning systems, data concentrators, altitude and speed measurement systems, flow angle sensors, just to name a few.

The avionics suite of the Tu-204SM aircraft is a latest achievement of the design bureau's division specialising in fixed-wing aircraft avionics.

The highly ergonomic flight deck is furnished with the advanced UIMDB KSEIS-204E integrated display and warning system featuring larger displays and trackball-type controls. The trackball control panel has allowed the implementation of interactive control of display of information and the use of menus, windows and the cursor. The pilots are now capable of getting the information required and delete the excessive information quickly and easily.

The novelties include a radically advanced systems class – general aircraft equipment control systems (Russian acronym – SUOSO). The advent of SUOSO has slashed the workload on the pilots, enhanced flight safety and, as far as the Tu-204SM is concerned, facilitated the transition to the two-pilot crew. The Tu-204SM is a stepping stone towards the so-called all-electric plane. The SUOSO-204 system was designed in such a way that it handled the flight engineer's job by itself. It is integrated virtually with all key aircraft systems (hydraulic system, landing gear, power supply, etc.) and handles control, warning and aircraft systems status monitoring.

The BSTO onboard maintenance system has been developed for the Tu-204SM. It has reduced the time and money required for servicing the plane. The avionics system also includes the SIVD enhanced-effectiveness/reliability digital air data system and advanced BSSI integral help system. The Tu-204SM airliner carrying the UIMDB avionics suite received its IAC Aircraft Registry certificate in late May 2013. The cutting-edge gear from UIMDB, used in the avionics suite of the Tu-204SM, increased flight safety by reducing the pilots' workload, slashing the weight of the avionics by 2.5 times compared to the previous version, increasing the extent of control and reducing the pre-flight preparation and maintenance time.

An impressive achievement displayed by UIMDB is the participation of all of its design divisions in developing the avionics suite for the MC-21 airliner. The company is developing the SUOSO-MC-21 aircraft equipment control system, and displays and control panels that are part of the integrated avionics suit and are making up the cockpit management system.

In the fixed-wing aircraft field, the design bureau's new lines of work include the development of airliner and freighter life support system controls, small plane integrated avionics suites and strap-down attitude and heading reference systems. For instance, UIMDB is running a programme on the development of the life support system control equipment to fit the MC-21 aircraft and the integrated avionics suite to equip the DA-42 plane.

In March 2014, UIMDB marked the 10th anniversary of its dedicated helicopter information management system development division. In the early 2000s, UIMDB JSC teamed up with a number of helicopter industry players and took part in four programmes on developing the avionics to furnish the Mi-28N helicopter (14 types of avionics products), Ka-226 (11), Ka-32A11BC (6) and Ansat (7). These days, the avionics in question is in full-rate production for both Russian customers-bound and export-earmarked machines and has numerous versions.

In 2010, Rosoboronexport JSC joins an Indian Defence Ministry-issued tender for 197 scout helicopters. To win, Kamov JSC fits a Ka-226T with Turbomeca Arrius 2G1 engines, while UIMDB JSC develops a version of the BISK system monitoring and displaying the status of the machine's powerplant and aircraft equipment and alerting the crew to the limit conditions. The helicopter passed all phases of the tender trials, with UIMDB personnel immediately involved in them.

In 2012, Kamov, as a result, issued UIMDB with the requirements specification for the development of the KBO-226 integrated avionics suite in two variants – the KBO-226TG-01 to fit the helicopter intended for the Russian Emergencies Ministry and the KBO-226TG to fit the machine designed for Gazprom JSC. The flight certification tests of the Ka-226T were complete in the third quarter of 2014.

Late in the 2000s, Rosoboronexport with the Mi-17V-5 helicopters comes up on top in the tender for a medium helicopter, issued by India. To develop the rotorcraft required, the Mil Helicopter Plant places a 'traditional' order with UIMDB for the development of the BSK-17V-5 airborne monitoring system. The system is developed in 2012. Now, it as well as the air data and emergency warning systems equips over 140 helicopters operated by the customer.

MC-21 cockpit

In 2009, Russian Helicopters JSC issued tenders for the development of an avionics suite for the Mi-171A2 helicopter – a heavy upgrade of the legendary Mi-8/17. UIMDB was selected as prime contractor for the development programme's KBO-17 avionics system development segment.

Mi-171A2 'glass cockpit'

Taking into account the high demand of the helicopter industry in up-to-date Doppler speed and drift angle sensors, UIMDB, asked by Russian Helicopters, made in 2012 a licence agreement with Canadian firm CMC Electronics for licence production of the CMA-2012C Doppler speed and drift angle senor. There has been a technology transfer and full-rate production of the sensor designated as CMA-2012C(R) has been under way under the agreement.

Building on the avionics development capabilities gained, the company has for as many as 10 years been developing and manufacturing hardware for military ground vehicles, developing displays and systems to equip combat onboard information management systems.

Using the requirements specification from NKBVS in the city of Taganrog under the Baget-BTVT-2010, Armata, Boomerang and Kurganets development programmes, UIMDB has developed the family of the VMMF-1, PMF-1-1, PMF-3, PMF-4 and PMF-5 multifunction panels based on high-resolution liquid-crystal panels with integral touch screens and/or push-button controls.

The company has developed the TsGI-1-var family of multifunction LCDs (MFD) with a compute core and push-button controls for the Signal research institute in the town of Kovrov. The LCD family has been cleared for production and is now fitting multiple-launch rocket systems, e.g. the Uragan-1M, self-propelled guns, e.g. the Msta-M, and other weapons systems as part of their automated sighting and fire control system.

An important step in the company's work on ground-based applications has been the modernisation of the 1L32 radar of the Khrizantema-S antitank guided missile system. The UIMDB-developed IM-16-5 MFD has ousted 11 units weighing a total of 90 kg plus, having become the 'heart' of the guidance radar.

For as many as 17 years plus, UIMDB has been running high-tech programmes on automation of hydroelectric plants and construction/reconstruction of small hydroelectric plants. At present, the power generation-related division of the design bureau has implemented more than 20 programmes, including five of them abroad.

Today, the company manufactures information management systems (KISS, SEI, BISK, BSK, SUOSO, SUOVO, SPKR, SOS), avionics suites, aerometric instruments and systems, sensors, control consoles, cockpit lighting equipment, lighting facilities and general industrial equipment. The company fulfils its contractual obligations owing to its production facilities and smooth cooperative links with such major Russian instrument makers, as Utyos in Ulyanovsk, Electropribor in Voronezh and Izhevsk Radio Plant in Izhevsk.

The availability of key basic technologies and pursuance of unique specialised technologies enable UIMDB to make cutting-edge products.

Speaking of production, one cannot but mention other key capabilities of the company. Now, UIMDB uses advanced surface mounting manufacturing technologies, moulded and welded joint quality control, effective quality post-mounting electronic module rinsing and precision waterproof coating application. A floor was set up for automatic painting and laser treatment of the light guide-equipped faceplates for cockpit control panels of aircraft, as well as for backlight parameter adjustment and protective lacquer coating.

Thus, UIMDB's technical renovation performed over the past decade has ensured closed-loop production cycle for the whole range of products made by the company.

The Checkout and Test Centre is what UIMDB is rightly proud of today. The Checkout and Test Centre has been certificated by the International Aircraft Registry in line with its aircraft and civil aviation installation rules and by the Federal Technical Regulation and Metrology Agency in line with its GOST R certification rules (Test Lab Accreditation Certificate No. IL-077).

Equipped with the latest equipment (mostly imported one), the Checkout and Test Centre conducts the following tests:

- impact of climatic factors;
- impacts of mechanical factors;
- compliance with electromagnetic compatibility requirements;
- high-intensity radiated field (HIRF) susceptibility;
- power supply requirement compliance;
- electrostatic discharge requirement compliance;
- lighting parameters requirement compliance;
- contaminating liquid (insecticides) requirement compliance;
- lighting-induced transient process requirement compliance.

Thus, designers of UIMDB and other Russian companies can run tests and research to prove the compliance of their products with the KT-160D, GOST V 25803-91, GOST RV 6601-001-2008, GOST RV 6601-002-2008, GOST RV 20.39.304-98, GOST RV 20.57.306-98, ENLGS-3, ENLGV-2 and GOST R 51318.22 standards.

UIMDB appreciates the current partnership with major Russian and Western firms, such as MIEA, KBPA, Prima, Aviaavtomatica, Detal, Omega, GRPZ, RPKB, Elara, Kontur-NIIRS, VNIIRA-Navigator, NIIKP, Monitor-Soft, NITA, NG LITEF, Rockwell Collins, CMC Electronics, Ametek, Ernst Diegel, TQ Components, Korry Electronics Co., LDRA, APC, Elbit Systems, just to name a few.

To ensure quality and meet the customer requirements, UIMDB has devised, has certificated, introduced and operated a quality management system meeting all current international and Russian quality management system standards:

- BS EN ISO 9001:2008 and EN 9100:2009 (AS 9100 Rev C);
- GOST ISO 9001-2008, GOST RV 0015-002-2011, GOST R EN 9100-2011;
- AP-21 Aircraft Certification Procedures;
- 21.2D manual.

The quality management system of UIMDB is part and parcel of its general scientific, production and economic activities management system aimed at meeting the customer requirements and expectations and covering design, development, production, maintenance and testing of components of airborne and ground-based aviation equipment.

Systemic work on refining UIMDB's quality management system enabled the company to become part of the OASIS international certified aircraft equipment supplier database in 2009 and annually prove its compliance with the international requirements to aircraft hardware suppliers.

PMF-5-1 and IM-16-5 multifunctional indicators

UIMDB has introduced an aftersales support system to maintain airworthiness and flight safety, assist customers (users) in learning operation of aircraft, improve their operation and maintain aircraft's quality and reliability.

A key element of the aftersales support system is the family of NASK Series 2000 ground-based automated checkout systems designed for checking out dismounted aircraft equipment. The NASK family is being used with success both in Russia and in many other countries.

Today, UIMDB is looking ahead with confidence, making its utmost to attain its strategic objective – honing its competitive edge and gaining leadership on the domestic and global aircraft radio electronic equipment within its current and newly-created competences.

Integrated modular avionics

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A promising line in the development of aircraft equipment is the integrated modular avionics (IMA) concept. It is the baseline principle for avionics of modern aircraft, such as the Boeing 787, Airbus A380, Sukhoi Superjet 100, F-35, T-50 and MiG-35.

The IMA concept is based on open network architecture and a unified computing platform, where software applications divide the common computing resources and act as systems. That way both the software and hardware are integrated on the IMA platform. As compared to federative architecture, the IMA concept allows a significant reduction in the avionics' weight and size.

The switch to IMA was determined by economic, organisational and technical prerequisites. On the one hand, there is an ever increasing need to expand the equipment's functionality and make it more convenient, while seeking to decrease its price and maintenance cost. On the other hand, the current and predicted technologies and componentry enable increasingly deeper integration on the hardware and algorithmic levels.

In 2004, GosNIIAS was the first in Russia to propose an R&D project containing the key principles of IMA-based avionics development. The IMA programme suggested wide cooperation between Russian aircraft instrument building companies and had the following aims:

- to integrate aircraft instrument building companies in terms of advanced technologies and solutions;
- to neutralise the effect when the companies are constantly raising the prices on their products because they are unique and, subsequently, not produced in large batches;
- to saturate Russia's market with competitive certified systems and offer them worldwide both as part of Russian aircraft and independently.

The works were ordered by the Russian Ministry of Industry and Trade.

The goal of the works was to lay the groundwork for manufacturing technologies of IMA-based avionics, develop technical solutions that would raise the equipment's quality and certifiability in the aviation registers (including EASA and FAA), promote Russian aircraft and equipment in the global market, as well as work out the technological and legal framework so that national manufacturers would equip aircraft with avionics using modern technologies and techniques.

The unique sci-tech groundwork was laid while implementing the project. It can save a lot of funds when developing and modifying the equipment, reduce the lead time and expand the range of tasks solved with minimum costs.

Dedicated to IMA's promising architecture and componentry, this article is the first one in a series about advanced manufacturing technologies for IMA-based avionics.

IMA CONCEPT

Integrated modular avionics is a concept of airborne equipment, based on open network architecture and a unified computing platform.

The computing platform is a base structure (crate) with a set of plug-in electronic modules (processor, memory, network switch and power supply ones). A module is designed under a common standard, meeting the principle of unification and interchangeability.

The role of the avionics' systems is played by software applications, which divide the common computing and information resources. Function is the key notion in IMA. A function means functional capabilities of the aircraft's hardware and software systems, following the principle 'one system – many functions', e.g., piloting, communications, indication.

IMA allows switching from the idea 'one system – one function' to the functional structure 'many functions in one computational core'. In practice, integration of functions, which was previously perceived as integration of systems, is performed in the new generation avionics by creating a database of functions and signals, as well as communicator of functions on the software level.

Modular software and hardware design of avionics is a natural result, that was reached due to the need to make aircraft componentry cheaper by increasing the number of manufacturers and enhance operational efficiency by making removable elements smaller than a unit.

Integrated modular avionics allowed bringing all control functions to the software level. As a result, the computing system's hardware was designed as a limited number of standard basic modules. Advanced real-time operating systems, in their turn, allowed setting up the software in the form of separate functional modules. Modular hardware and software is the key to unification, standardisation and, consequently, lower developing and production costs.

Conceptually, Russia's IMA project is developing along three main lines:

- hierarchical system of specifications;
- componentry of the computing platform and peripheral equipment;
- functional software.

Functional software modules are commonised by their interfaces to the level when they are interchangeable from different suppliers. The componentry of the platform and peripherals are standardised by information, electrical and mechanical interfaces to the same level, too. Due to deep unification, removable parts from different manufacturers would become interchangeable within one aircraft. This would make upgrades easier and, consequently, create favourable conditions for competition and price reduction.

AVIONICS INFRASTRUCTURE AS CENTRAL ASPECT OF IMA

The promising avionics suite should have open network failure-proof functional-oriented architecture, based on scalable IMA using a commonised computing environment (platform). Several IMA platforms can simultaneously operate in an aircraft's avionics suite, enabling its distributed architecture. To ensure information exchange between functions, sensors and executive components, the IMA platform uses AFDX communications protocols that enable efficient arrangement of network dynamic structures.

Open architecture implies that devices with different purpose, like information sensors, can be connected to the systems' computational core via standard concentrators. Functional software resources are distributed under the control of a real-time operating system.

An important feature of architecture like that is that there are no rigid, once and for all established ties between the avionics' sensors (information channels) and computing aids. This enables dynamic reconfiguration of the avionics' structure by redistributing the resources in a relevant way. To efficiently perform each of the avionics' functions, structures are formed inside the computing environment (connecting to the system's information channels). Noteworthy is that each of the structures is formed only for the period required to perform the function. That way the overall configuration of the computing environment dynamically rebuilds itself while the avionics are working.

GosNIIAS is currently working to upgrade the 2nd-generation IMA platform, enhance the cockpit's functionality, include general aircraft equipment in IMA (connected through remote concentrators), as well as use several distributed IMA systems. At the same time, the general aircraft systems would become part of the airborne computer network's information resource.

This would streamline the avionics structure in terms of the following important parameters:

- improve weight and size due to fewer connection wires;
- raise reliability by reducing the number of external effects, influencing the avionics;
- minimise the quantity of primary sensors, required for the avionics to perform their functions.

The following systems can be regarded as general aircraft equipment: hydraulic, electric supply, fuel, landing gear extension and retraction, air conditioning, cockpit pressure control, wheel braking, taxiing, crew oxygen, additional power supply, fire fighting, anti-icing, door and hatch, lights systems, etc. The functions of these systems should make maximum use of the avionics' general computing resources, too.

The following steps need to be made to integrate the general aircraft equipment into a common network:

- to write adequate algorithms of the system's functioning in the form of mathematical models;
- to develop remote network concentrators that would remain operational in severe conditions and could, if necessary, perform some of the system's functions;
- to develop adaptive digital primary sensors with standard interfaces that would perform primary data processing;
- to offer design solutions for electric executive devices with digital inputs and proper characteristics.

The 2nd-generation IMA platform provides new design solutions for the functional modules, crates and IMA units. The processor modules are based on high-performance multi-core microprocessors with low energy consumption. The graphical modules should produce 3D imagies having a resolution of at least 1920x1200x60 Hz. Efficient cooling techniques of high energy emission systems are being implemented in compliance with the ANSI/VITA 48.5 standard. The removable modules and crates are made of light composite materials.

The promising structure should incorporate highly integrated multifunctional systems, for example, unified software-controlled IMA:

- widely use commercial hardware and software components (COTS components) to reduce the cost of avionics;
- make the software independent of the hardware used;
- create an integrated automated environment of avionics development processes, based on intellectual systems, modeling and virtual prototyping;
- introduce efficient built-in control assets to improve failure safety and maintainability.

The conceptual guidelines in the development of next generation avionics are as follows:

- developing a lineup of unified open failure-proof network architectures, based on scalable IMA, in order to enhance reliability, data exchange performance and jam resistance and decrease the weight of communication lines and input/output devices;
- applying advanced interfaces (aviation Ethernet, Fibre Channel, RapidIO, Wi-Fi) and communication protocols (TTP) in the IMA platform, between the functions, sensors and executive components, ensuring efficient arrangement of dynamic network structures;
- further unifying the modules and components in order to reduce the number of avionics components and their development time, weight and size, as well as raise their performance, reliability and failure safety.
- implementing advanced design solutions for functional modules: multi-core processors, graphical modules producing high-resolution SD images, uninterrupted power supply units, highly reliable network switches, etc.

AVIONICS COMPONENTRY

The key unified avionics components are the crate's base support frame (BSF), general-purpose processor module, network switch module, signals concentrator module, optical/electronic converter unit, power supply unit, indicators with graphical processors and indication panels. The computational core consists of the following hardware components: the removable module's BSF, as well as graphic controller, mass memory and input/output slots. Breadboards of the abovementioned components in the 3U and 6U form factors have already been developed.

It is important that the avionics consist of a minimum number of unified interchangeable open standard components (modules, systems), which feature high performance and energy efficiency.

The introduction of these components will facilitate import substitution in promising Russian aircraft.

CONCLUSION

The promising avionics should be based on IMA with open network architecture, using a wide range of standard technical solutions and unified hardware and software. High level of standardisation and unification allows demonopolising the project by means of broad integration of companies and distributed organisation of the works, as well as reducing development costs, time and risks due to the minimum number of unified systems required, among them Russian and foreign civil- and dual-use COTS components.

A common multi-role failure-proof integrated computing system should be used. In this case, most of the avionics' functions would be performed by the same hardware platforms of the computational core. The latter would be built using cutting-edge elementary base that can be further expanded and upgraded. This approach essentially divides the developers of hardware and software platforms and creates a market of software products, including reused ones.

All components should have a standard crate modular design, and the elements should be easy to change. This allows strongly reducing maintenance costs and simplifying the equipment's improvement.

A crucial element of the IMA programme is the development of standardised avionics for the broadest possible class of aircraft. This would do away with the monopolisation in the development sphere.

Cockpit instrumentation from ELARA JSC

multi-role color plasma display

BNK-3U base support frame unit

AFDX controller

Components of the computing platform from the St. Petersburg Electroavtomatika design bureau (unified BSF bodies)

Remote concentrator from Kotlin-Novator

the VPX-3U remote crate (BSF) of the digital computer

processor module

processor module

Building blocks of high technologies

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The Institute of Aircraft Equipment (NIIAO) was set up in 1983 to devise avionics development concepts and work out the avionics' future characteristics. This was the key tasks among a wide enough range of tasks assigned to the newly-established organisation.

The development and implementation of the first generation of Russian digital flight navigation systems made Russian avionics complaint with international standards and prepared NIIAO's scientific, technical and production capabilities and personnel as well for the next major step in the evolution of Russian avionics – the development of the IKBO-95 integrated avionics suite designed to equip Russian advanced multirole amphibian Be-200.

The development of the IKBO-95 implemented a number of advanced technical solutions meeting the fundamentals of the latest integrated modular avionics suite development concept, including the following:

- deep integration of central computer systems through transition to commonised computing modules and standardised supporting frameworks;
- wide-angle flat-screen full-colour LCDs;
- integrated aircraft navigation system and 'smart' control panels;
- feasibility of quick modification of the master software programs of the systems via software package upgrade and download by a data loader without having to modify the hardware.

NIIAO developed commonised computing modules, design and programming systems and interfaces, with the results serving the 'avionics core' – a central computer system consisting of a commonised hardware platform and software functional modules, including the following:

- flight and thrust automatic control module;
- operating limitations and flight parameters overshoot warning module;
- maintenance and failure collection/pinpointing module;
- voice and tone signal synthesiser module.

In 2001, a joint team of personnel with the IAC Aircraft Register, Beriev and NIIAO certificated the configuration of the integrated modular avionics of the Be-200 amphibian. The IAC Aircraft Register gave the nod to the hardware/software platform of the computer system and then the functional modules making up it.

Now, the incremental certification procedure, spelt out by Western regulations (Do-297, TSO-C153, etc.) and draft Russian certification regulations, has been devised and tested.

The procedure has been followed by the developers of components and systems within the framework of the development of 'the integrated modular avionics suite' (IMAS). The development has been under way since 2011 under a governmental contract signed by the Russian Industry and Trade Ministry and a number of aircraft instrument industry players under the 2002–2015 Civil Aircraft Industry Development Federal Programme.

The aggressive development of IMAS kicked off in 2011, having covered virtually all of the components of the present-day avionics suite and having boiled down to the development, testing and certification of avionics prototypes in accordance with all current and future Russian and international aeronavigation and certification standards. Over the past three years, the company has developed a family of prototypes, the design and certification documentation and software, commissioned several component and system integration, debugging and test benches and conducted preliminary tests of prototype avionics.

Within the framework of the 2013 efforts, NIIAO built an integration bench designed for integration tests of the newly-developed equipment in various configurations ranging from the avionics suite of the MC-21 airliner to that of a regional passenger aircraft and even a general-purpose aircraft.

Under the IMAS development programme, NIIAO has been appointed by Concern Radio-electronic technologies (KRET, prime contractor for development) the avionics integrator, with its subcontractors including such renowned companies as the Ulyanovsk Instrument-Making Design Bureau (displays, consoles, air data systems, general aircraft equipment control systems, strap-down attitude and heading reference systems), Moscow Institute of Electromechanics and Automatics (computing platforms for control systems, aeronavigation function, strap-down inertial navigation systems), Aeropribor-Voskhod (flight environment data systems), Tekhpribor (automatic fuel management system sensors), Aviaavtomatika (helicopter flight data recorder systems) and Izmeritel (aircraft monitoring and recording systems). All of the above companies are subsidiaries of KRET.

In addition, development subcontractors include third-party companies, e.g. VNIIRA (navigation and monitoring systems), Polyot (radio communication systems) and Kontur-NIIRS (weather radar).

An objective of the IMAS development programme in 2014 was integration bench tests of the equipment developed. When NIIAO started devising a test programme early in 2014, it turned out that there were no interfacing protocols for most of the in-development products interacting within the actual avionics suite. In the end, NIIAO and the developers of the affected systems had to tackle the problem.

Ultimately, we upheld our right to integrate all avionics under the programme. In so doing, the Concern Radio-electronic technologies played a very important and productive part, with the concern's development strategy declaring its endeavour to become the major supplier of integrated solutions for both commercial and military aircraft.

The integrated modular avionics concept itself consists in the development and certification of a commonised computer platform with a real-time operating system ensuring the integration and compartmentalisation of software applications – software functional modules, as well as a set of commonised open ARINC 429, ARINC 664 and ARINC 825 interfaces easily accepted by any applications.

Over the past three years, NIIAO and its subcontractors, including the Ramenskoye Design Company and Saratov Electric Instrument Plant, has created under the development programme a family of computing platforms based on various integrated modular avionics modules and submodules. These are computing modules, graphics processing unit submodules of various

IMA integration stand designed in NIIAO

throughput, and mass storage and aircraft interface modules and submodules. In addition, the same modules can be used as add-ins for other functional systems.

Now, more than five variants of IMAS systems wrapped around such modules and submodules are being tested at NIIAO's integration test bench:

- airborne computer system – an integrated modular avionics platform in two module configurations (high- and medium-performance processors) and in two supporting frame variants – one for planes (ARINC-600) and the other for helicopters (no forced air cooling and no frame);
- integrated airspace surveillance system based on the automatic dependent surveillance broadcast data;

Radiation-hardened computer, multifunction display and head-up display from the St. Petersburg Electroavtomatika design bureau

Air data system developed by UIMDB JSC

- integrated navigation and landing system reliant on the signals of the GPS, Galileo and GLONASS satellites constellations, augmented by GBAS and SBAS stations.

Interestingly, the development and kickoff of the testing of the integrated navigation and landing system co-developed by NIIAO and the NAVIS design bureau coincided with the commencement of the joint trials of the Russian SBAS segment, SDKM, which deployment was completed by Russian Space Systems in 2014. Joint tests of airborne and space-based segments of the satellite application are planned in 2015 as part of the flight tests under IMAS programme.

Special mention should be made of the efforts to introduce an ARINC 653-compliant real-time open commercial operating system into avionics systems and, in the first place, integrated modular avionics modules and platforms. The introduction of the operating system as well as the basic rules and applied functional and system software development and interaction principles has allowed the perception of aircraft-related software as a commercial products of its own, approved by aviation authorities for use as part of certain configurations of integrated modular avionics platforms and systems.

It stems from NIIAO's experience that the transition of a rather complex software product from one hardware to another (both having the OS 653 operating systems) took about a month and a half. Previously, this kind of work without using the operating system used to take more than six months due to the need of adapting the software to a particular hardware platform.

Open architecture allows quick and easy software migration from one platform to another. It also allows integration of several functional applications within a single hardware resource, while preserving their compartmentalisation, i.e. they operate within the same environment but are independent and certificated and approved by aviation authorities independently.

Every functional module undergoes all types of verification and testing. It has standard OS interaction interfaces and ports, from which it receives and to which it transmits data. All of this has been governed and standardised by rules. Then, upon completion of the off-line tests, the functional module is integrated with the integrated modular avionics hardware platform, system software and other functional modules (if needed) for integration tests of the integrated modular avionics system in the configuration required.

The performance of present-day computing resources is so high that a processor can handle virtually all of the functions of a commercial aircraft's avionics suite.

Nonetheless, for the sake of reliability, many functions and hardware resources are made redundant and 'critical functions' are implemented in heterogeneous (hardware and software) loops to prevent uncontrollable failure due to an encapsulated design error.

In the final analysis, having a set of ready-for-certification modules, one can quickly and easily enough make a complex in the configuration required.

In real life, situations occur from time to time when an object needs three or four computing modules, while another may have all of its function integrated with a single module. This is particularly applies to small aircraft, for which the need of an extreme reduction in the number of hardware units and in their weight and power consumption while retaining virtually the same functions an airliner has is especially urgent. To cap it all, the implemented functions are almost the same, while the price is far lower!

Now, the integration of a functional software module being developed 'by the book' under the IMAS programme takes a platform integrator and a software developer a week or two. Under the programme, more than 10 functional applications are integrated at NIIAO's integrated modular avionics platform.

It took personnel with the Moscow Institute of Electromechanics and Automatics mere three sessions to install and integrate their Aeronavigation Computer System application with the whole of the complex. It took Polyot experts in Nizhny Novgorod about the same time to install a digital communication control and routing software functional module.

Special mention should be made of the work in the field of small aircraft avionics. NIIAO is developing an avionics suite for small planes. Two years back, the institute competed in an L-410 avionics modernisation tender held by Czech company Let Aircraft Industries. A commercial offer and a draft proposal based on the groundwork available were worked out and submitted. The competition was won by Garmin that offered a price and a weight twice as low as those offered by NIIAO.

At present, given the progress made in the IMAS development, we can achieve the equipment integration level comparable to that of Western manufacturers in terms of both weight and technical characteristics.

Mention should be made of another task facing the institute, namely flight tests of the equipment being developed under the IMAS programme. Flight tests are sine qua non for IAC Aircraft Registry approval, being essentially the green light for further commercialisation of products. This implies a hefty reduction in the time and volume of work on the aircraft from the point of view of future fixed-wing and rotary-wing aircraft development programmes. In the first place, this applies to the MC-21 programme providing for using numerous components and systems used as part of the IMAS.

To meet the objective, Concern Radio-electronic technologies has signed agreements with Tupolev and Beriev for the use of Tu-214 and Be-200ChS prototypes for the flight trials of the advanced avionics. It is worth mentioning that the work is equally interesting to both parties. The planes get a new quality, a new functionality, including the functionality obligatory for introduction in line with international requirements, while the KRET subsidiaries finalise the newly-developed equipment test and certification phase.

For instance, we want to fit a drastically advanced air data system from Aeropribor-Voskhod to and test it on the Be-200ChS. Under the present-day certification standards, including the EASA ones, 'critical functions', which include flight environment data measurement, need a proof of the practical impossibility of uncontrollable failure, which is impossible in case of the system's homogenous design. We suggested a new measurement channel based on a different principle should be added to the two measurement channels onboard the aircraft and achieve the compliance with the customer's requirements by means of the channels' heterogeneity.

The Be-200 used as a flying testbed offers another positive effect. The aircraft holds an AESA certificate. Under the current rules, newly-installed equipment may be certificated by EASA as part of the aircraft as a secondary or primary baseline design modification, depending on how critical the equipment is. Thus, advance tests can be conducted and EASA experts can be familiarised with various configurations of the equipment developed under the IMAS programme and earmarked for equipping future aircraft, the MC-21 in the first place.

Element base of network-centric control

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Innovative technologies and products drastically change the structure and application of new and previously known equipment and materials, which brings about the need to upgrade the methods and tools of controlling different systems and processes.

Intellectualisation and cybernation of control systems form the comprehensive strong interconnection of events, phenomena, processes and objects in space, time and results (information environment). This is vital to control very large systems (industrial, military, information and computing ones) using cybernetic methods and models of their functioning.

Being at the top of very large network systems, economy, finance and security management systems serve as an example of applying high-end information technologies. They automatically gather, classify and process data, elaborate and supervise the execution of responses to current and, primarily, emergency situations and substantiate plans for the future.

Network-centric systems (NCS) and network-centric control (NCC) are to be implemented in order to radically improve the quality of both routine and crisis management. This will enable systematic and integral approach to the control over distributed subsystems and lower-level objects (industrial, combat information and control ones) that use strongly interconnected information.

Higher quality of control on all levels is achieved by performing proper gathering, timely targeted classification of multi-factor information on all NCS sublevels and its further analysis and processing using the algorithms that are adequate to the current scenario. In this case control is exercised with clear understanding of the integral dynamic information picture of the actual and predicted environment and the systems' components, including that in critical conditions and compelled modes of self-organisation of subsystems and processes.

To harmonise the efforts and methods, while performing their tasks the objects and subjects of lower subsystems create information in the higher control body, basing on the analysis, generalisations and data on the decisions made.

NCC's importance and efficiency is determined by response dynamics, profound coverage of objects and subjects in algorithm structures, their correspondence with possible scenarios, application conditions and the computers' performance.

NCC has the following properties and specific features:

- systematic and functional shaping of a versatile NCC algorithms structure, which embraces all types of activity in the system;
- employment of algorithms for distributed information processing and control with high intellectualization levels;
- high resistance to the failures of network nodes and communication lines, as well as resistance to unauthorised actions.

Military control systems are difficult to make the network-centric due to the following reasons.

First. Unity of command means not only embracing the evident current tasks and processes in terms of space and time to provide immediate response. It also implies a wide range of multi-aspect strategic control challenges.

To be able to impact the processes and objects timely, accurately and efficiently, one requires reliable models, which allow taking into account strong interconnection of multi-factor globally distributed information and making well grounded forecasts.

Second. Strategic and tactical (situational) control in an NCS should be harmonised, unified and continuous.

Third. The outstripping growth of strongly interconnected, multi-factor, dynamically changing and sophisticatedly structured information in large and very large NCSs demands that the system should be scalable and cyber secure.

Fourth. The planned quality of control is hard to achieve due to the exponentially growing span of control over own information and computing resources, as well as amount of expertise, labour, time and money required to integrate its components.

Modern branch-wise and military NCC assets are developed using different software that have two logically unlinked levels of backbone 'standards':

- computational nodes are based on computers with heterogeneous microprocessor architectures – implementation of John von Neumann's model (classical computer axiomatics) as a logic basis for industrial production of computers, software and information technologies – and versatile calculations, which are possible with relatively simple engineering solutions that can be further produced using contemporary elementary base (EB);

- TCP/IP protocols ensure scalability of global and local computer networks, as well as reliable data exchange between computational nodes via various routes.

In this connection, it is worth mentioning the fundamental features of classical axiomatics, preventing the building of NCSs:

- calculation rules allow continuous reproduction of diverse incompatible data forms and software and an infinite variety of computer hardware designs;

- versatile programmability can be originally implemented only in inter-computer resources and the operating system.

The abovementioned features are inherited by multi-level diverse network equipment and nodes in networks – computer devices using microprocessor EB with classical computer axiomatics and relevant protocols and resources.

Large network systems cover different spheres of processing distributed information. Limited in terms of development capability, they demand plenty of funds and time and often remain incomplete. In addition to being sophisticated they require development of multiple diverse, hardly compatible software/hardware solutions that would integrate heterogeneous network resources in the form of multi-layer superstructures, such as 'computing nodes – von Neumann model' and 'links between nodes – data exchange protocols' that connect the initially unlinked levels of backbone standards.

NCC's implementation presumes wide employment of network computing technologies. However, no logically integral network computing model, as the basis of computer industry, has been developed so far to replace von Neumann's model. Consequently, local narrow-purpose solutions, such as Grid- and Cloud-technologies, are dominating today. They are expanding application spheres of distributed systems in heterogeneous network resources on a local (corporate) scale. As a result, this continuously reproduces the diversity of computer environments, caused by an increasing size of NCC tasks and systems. This raises the complexity and the required amount of labour, money and time. As a result, a dent is made in the systems' integrity, reliability and cyber security.

The 'curse' of size and growing complexity of integrating heterogeneous network resources is becoming a fundamental problem of creating NCC's unified versatile algorithmic space in arbitrary large networks and an iron curtain in the development of NCSs, covering various branches or theatres of land, water, air or space operations. The existing technologies of making distributed systems set limits to their size and functionality and do not cover all resources of the global networks. Total build-up of computing resources is being done to overcome the problems and avoid waste of efforts and time.

A common information and algorithmic space is required to utilise the advantages of NCSs. It would ensure comprehensive integration of diverse complex software and information and computing resources to embrace network resources by branches of the economy.

In order to create a common versatile algorithmic space of NCC in arbitrary large growing networks, the initial objective would be the development of EB relying on non-microprocessor universal architectures.

The problem of network centrism cannot be radically solved using von Neumann's classical computer axiomatics as it does not provide for network computing. For this reason, we need a transition to a versatile model of seamless programmable distributed computing in arbitrary large networks. The forms of data and programmes representation would be mathematically set up top-down on its basic postulate level.

The specific features of the new model:

- the initial causes for the reproduction of the diversity of globally distributed computer information (data and programmes) are eliminated on the postulate level;
- versatile seamless programmability is applicable to any, even arbitrary large networks;
- a versatile, mathematically homogeneous, freely scalable, seamless programmable algorithmic space of distributed computing and network-centric control in arbitrary large networks is being formed;
- mathematically homogeneous structures for representation of globally distributed data, programmes, processes and systems in such a space do away with the complexity of integration tasks, typical for heterogeneous networks;
- channels of unauthorised access are completely locked, and cyber security requirements are met;
- the amount of labour and funds required to build and integrate NCC systems no longer depend on the networks' size and reduce drastically.

A model like that requires a new class of versatile single-chip network computers with non-microchip architecture.

A single-chip network computer is in essence a large smart random-access memory with integrated system intellect. It features:

- the key functions of operating systems' core (controlling input-output, dynamic memory relocation, multitask programme execution and network data exchange), which drastically decrease the complexity of digital resources' functional integration;
- versatile computer basics of seamless programming of distributed complex computations in network resources;
- protection against unauthorised access (hardware isolation of the physical memory space from intrusions);
- built-in routers and secure protocols that support scalable, seamless programmable distributed computations in cyber secure networks.

The transition to the single-chip network computer architecture is a key to achieving network-centrism with limited funds and time. Hence, look-ahead development of EB manufacturing technologies based on new computer network architectures is required.

Major projects of network systems for distributed data processing

Name	*Aim*	*Means*	*Price*
Future Combat System (FCS), US Army (since 2003)	*Integrating all manpower and hardware involved in a military operation into a single command network*	–	*$177 billion (terminated early, aim not achieved)*
The LHC Computing Grid. The Large Hadron Collider, CERN	*Processing 1,500 terabyte annually using 10,000 computers*	*Grid computing, 100 organisations in 31 countries*	*Over $500 million*
Svyazinvest, Russia (2005–2008)	*Providing services to 40 million users of cable communication networks. Making an integrated billing system (instead of 180 billion systems from different manufacturers)*	*AmDoc + IBM*	*$480 million (not fully implemented)*

KRET

Concern Radio-electronic technologies JSC 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. Concern Radio-electronic technologies 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. Concern Radio-electronic technologies was set up in 2009. It comprises 97 subsidiaries throughout Russia.

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