Military Thought

The Defense-Industrial Complex of Russia and Advanced Technologies

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Abstract. The paper examines the science-and-technology system and its top-priority area, the rocket-and-space sector of the defense-industrial complex (DIC). The author goes over the R&D priorities for nanotechnology development in Russia in the interests of defense industry enterprises.

Keywords: military technology policy, nanotechnology, weapons, defense-industrial complex.

The conception of long-term socioeconomic development of the Russian Federation outlined the future of Russia's economics and social sphere within the innovative development model. To carry out the tasks specified therein will take a profound technological modernization of all economic sectors, and also a national innovation system.

While estimating the current state of the domestic science-and-technology system (STS) it should be pointed out that Russia is among the world's leaders in several major trends and projects, including in such areas as nanotechnologies, nuclear and hydrogen power engineering, energy-efficient systems, development of applied programs, and environment protection.[1] Russia can still boast a sizeable personnel potential in the science-and-technology sphere, although its quality, alas, is deteriorating.

The worst problem faced by the Russian science-and-technology system is the considerable gap between the available resources (science-and-technology potential) and the effect from tapping them – production and export of high-tech commodities and technologies.

The Russian technologies market has no solutions needed by business. On the one hand, Russia's R&D sphere cannot satisfy the current high demand of rapidly developing companies for new high-tech solutions in individual sectors (electronics, telecommunications, etc.). On the other hand, the technologies developed on the public money (within the framework of critical-technology support, departmental mega-projects, etc.) often fail to match the makeup of real requirements by the companies. The chief obstacle to the reproduction of science-and-technology potential in the country and proper innovative activity is *lack of an integral national innovation system*.

The sequences of innovative product making in Russia have been ruptured: basic research does not grow into the applied kind, which is not followed by R&D, while the latter do not result in industrial production. The sequence elements are separated from one another, and each one is focused on its own problems. The pattern at work is as follows: Russia's high-grade research potential is incorporated in foreign innovation systems (FIS); our more advanced basic research projects and individual technological solutions are integrated in the production chains of Western corporations; Russia's science-and-technology potential that failed to join foreign innovation system is not overly concerned with the needs of domestic business, and is poorly capitalized accordingly; the domestic market's demand for high-tech products is met by Western manufacturers, including those that made use of Russian theoretical and technological developments in their production.

Within the next ten to fifteen years, Russia's position in the global market of defense industry technologies, products and services is unlikely to be shaken, as far as aviation, space, air defense units, and automatic rifles go. But in the long term (after 2025), Russia will have to find a new technological niche. Analysis of this country's position in the world market of knowledge-intensive products and services suggests the ***rocket-and-space industry*** as a prospective defense-industrial complex priority.

The point of technological development in the rocket-and-space industry is to secure technological leadership in the selected market segments. The original competitive advantages of Russian-manufactured carriers in the launching market have been mostly leveled out by now and are displaying a steady downward trend, which is due both to the way things are in the industry itself (production facilities getting obsolete, technological discipline worsening, personnel potential deteriorating, etc.) and to some factors outside the industry. In the circumstances to persist with the former strategy of Russian carriers market supply that relies on "cost leadership" is no longer possible. Russia may work for maintaining its share of the launching market as a strategic market goal, but not at all costs, because with the resources as limited as they are, this may, on the one hand, reduce Russia to the role of a space cabbie, while on the other, it may result in neglecting the other space sectors. Among the technology policy priorities in this area can be the following lines:

– building new-generation space complexes and systems whose technological specifications would make them highly competitive in the world market (developing long-life modern carriers for launching satellites into orbit; doing spadework for breakthrough projects in the area of space technologies and outer space research);
– completing work on the GLONASS system (deploying a satellite group based on new-generation apparatus with a long active life (of no less than 15 years) and improved performance attributes, creating a ground-based control unit and equipment for the end users, promoting that to the world market, and ensuring GLONASS and GPS facility compatibility);
– developing a satellite group (creating a group of communications satellites to boost employment of all kinds of communications, fixed, mobile, and personal, throughout Russia);
– creating a group of weather satellites capable of transmitting data in real time;
– devising orbital platforms to accommodate various specialist and other kinds of equipment that can be serviced and replaced;
– expanding Russia's presence in the world space market (retaining its leading position in the traditional markets of space services, such as commercial launches, increasing its presence in the market of commercial spacecraft manufacturing, promoting more vigorously separate components of space missile equipment and corresponding technologies to external markets, entering high-tech sectors of the world market, such as production of ground-based facilities for satellite communications and navigation, remote-control Earth probes, modernizing the Russian segment at the International Space Station (ISS).

The estimated amount of money required to fund the development of the rocket and space industry along the innovatory lines over the next 20 years is 3.5 to four trillion rubles for production and 300 to 400 billion rubles for investment. There it is necessary to single out the **main trends in technological work** to execute the state defense order and the state armaments program.

For the *Strategic Missile Forces* and the *Navy*: developing high-energy solid propellants, structural composite materials for solid-propellant rocket engine cases, and thermoinsulation materials for these engines; creating high-durability electro-radio items; completing work on multifunction screen protecting coating.

For *missile attack warning systems*: developing infrared matrix photodetectors, cryogenic deep-chilling systems with an increased replacement life, software and cell bases; reducing the weight and size of spacecraft and introducing micro-spacecraft technologies.

For *reconnaissance*: manufacturing large light-weight mirrors; devising matrix image detectors in the visible and infrared ranges; developing cryogenic devices; developing a radar with active phased antenna grid-based aperture synthesizing; building big antennae; developing onboard computers with a productivity of 109 operations per second; developing high-sensitivity onboard radars of the Doppler type; developing onboard mm-range retransmitting units and onboard optic-range retransmitting units; creating a radiation-resistant cell base for specialized and utility spacecraft communications and combat control systems.

For *communications and combat control*: creating small-size high-production onboard digital and computing machines, means of communication and data transmission, including means of laser intersatellite communication; developing comprehensive combat programs for command posts and efficient pooling of data from heterogeneous information sources; creating means of detecting ballistic missiles based on new principles of collecting and analyzing information about the characteristics and methods of combat employment of aerospace attack facilities by the would-be adversary.

In terms of performance attributes, domestically manufactured specimens of space rocket equipment made under federal target programs are on the whole expected to have attained world-class standards by 2015. Yet to achieve full parity with the items manufactured in leading foreign states in all technical and economic indices, and to ensure superiority of advanced domestic space rocket equipment in the future, it is necessary to have extra resource support from the state for target technology work. The general condition for implementing the optimum version of technological development for the rocket-and-space industry is to have Russia's entire economy embrace innovative development and carry out other tasks specified in the Strategy of Russia's Development until 2020. In particular, a sine qua non is restructuring the defense-industrial complex, ensuring high development rates for domestic science and education, and their synergy, and for related economic sectors (above all, the electronic industry within the framework of defense-industry programs of the Union State).[2]

Employment of nanotechnologies is based on drastically improved consumer properties of technological products, way above the current level. The potential of nano-size matter particles is based on the difference between the energy state of atoms on the surface of the nanoparticle and in the volume of the matter. Outside atoms have free valence ties, which in the case of inside atoms go to interact with neighboring atoms. In the case of liquids, the free valences of outside atoms create surface tension, which can be graphically visualized if you recall the easy gliding of pond-skater insects on the water surface. In the case of a solid body, the presence of surface energy is less obvious, has no graphic proof, and is practically ignored in daily life.

Within the nano-size range things are different. If the particle is of a certain size known as critical (D_{cr}), the impact of inside atoms on the properties of the matter is offset by the influence of the outside atoms' free valences. If the particle is smaller than D_{cr}, their influence becomes more powerful, and the properties of the matter change radically.

Then the laws at work are those of quantum mechanics. This type of particle is called nanoparticle. The word *nano* translates as *dwarf*. One nanometer equals 1×10^{-9} m. Nano-size particles belong to the matter whose size in at least one dimension is less than 100 nm. Nanotechnologies are fairly profitable. This is a promising line for investors. In the case of designers, this is a chance of dramatically improving consumer properties of nanomaterials in advanced articles. As for businessmen, they will be able to create enterprises for manufacturing products far higher in quality than the current standards.[3]

The R&D priority trends in nanotechnology in Russia are as follows: civilian- and dual-purpose structural materials with specific exploitation properties (first and foremost, durability and temperature properties); materials and technologies for nanoelectronics and nanophotonics; carbon-based composite materials (carbon nanotubes, fullerenes); research and technological equipment for the nanoindustry; medicines and biomaterials. Nanotechnologies and new materials are a trend that can radically change the life of humanity and make an enormous contribution to socioeconomic progress in the near future. According to expert estimates, the projects most topical for Russia in this area are to do with membrane making and catalyst systems, biocompatible materials, polymers and crystalline materials. Not quite so bright are the prospects of technologies for making and processing composite and ceramic materials, and also nanotechnologies and nanomaterials. Speaking of membranes and catalyst systems, the more important technologies there are precious metal catalysis with nanosensoric nanoparticles in oil processing, ecology and energy saving; nanomaterial-based filters and membranes for water and air purification, and desalination; and also technologies of catalyst synthesis of carbon nanomaterials – nanofibers, nanothreads, and nanotubes made of available carbon.

The best way of using biocompatible material technologies is in medicine: nanostructured materials and coating for implants designed to endure pressure; nanocontainer technologies for vector medicine delivery; biocompatible materials imitating living tissues; nanomaterials for urgent arrest of bleeding in first aid; magnetic nanocarriers with a regulated Curie point to treat malignant tumors, deliver medicines and perform magnetic tomography. Employment of polymers and crystalline materials is fairly diverse. There are crystalline and nanostructured metal materials for various kinds of transport; extra-strong and chemically resistant polymeric materials (including fibers and threads); antifriction polymeric materials and coatings, and also crystalline materials for infrared equipment, spintronics and photonics. Considerable effect is expected to result from new materials in power engineering, above all alternative energy sources (solar batteries, portable fuel elements, hydrogen accumulators, electrochemical and thermoelectric sources of current, supercondensers, etc.).

As far as composite and ceramic materials go, the potentially biggest market is for strengthening instrument coating in machine-building, corrosion-resistant materials and coatings for extreme exploitation conditions, high-transparency nanoceramics for optics and photonics, nanocomposites for fuel elements and nanoionic devices, and resource-saving ceramic membranes with precision-regulated porosity. Highly topical for Russia are projects related to metrological support, and also nanoapplications in the area of electronics, including the cell base, metamaterials for optoelectronics, sensor equipment, magnetic tomography, microscopy of ultrahigh definition, formation of three-dimension semiconductor and metal nanostructures based on self-organization effects, and creation of extra-capacious energy-independent devices for long-term data storage. As in the polymer area, use of nanotechnologies appears highly promising in power engineering, e.g., devising superbright and efficient white light-emitting diodes. In the area of nano- and microsystem equipment the more topical are applications to do with high-speed communications securely protected against natural and artificial interference, modeling nanoinstruments (nanotransistors, etc.) for ultrahighly integrated chips with design standards in the sub-20 nm range. Also promising are technologies for making polyfunctional diamondlike films and fine dielectric films sub-20 nm thick with a big dielectric constant (~ 20). An important trend for power engineering is creation of supersensitive sensors of physical values with a radiation resistance above that of silicon.

The level of Russian projects under the priority trend of Nanosystem and Nanomaterial Industry is fairly high, but in most sectors we are lagging behind the world leaders. Russians are doing best in the area of membranes and catalyst systems, composite and ceramic materials. They get somewhat lower marks for nanotechnologies and nanomaterials, and also biocompatible materials.

Among the technologies where Russia is lagging behind less obviously the ones worth mentioning are formation of ultrafine-grained structure in metal alloys by intensive plastic deformation; conjugation of nanocontainers with biologically active molecules; highly efficient polymer thermoinsulating heat- and fire-resistant materials; coatings and modifiers; corrosion-resistant materials and coatings for extreme operation conditions.

In a number of areas we have tangible chances of quickly putting to use Russia's science-and-technology stock and obtaining competitive products: these are strengthening instrument coatings for machine-building, crystalline and nanostructured metal materials with improved structural and functional properties for various kinds of transport; corrosion-resistant materials and coatings for extreme operation conditions; nanomaterial-based filters and membranes for water and air purification and desalination.

On the whole, research and development in the nanoindustry chiefly rely on the domestic stock in a wide variety of segments. In the area of basic research, the results achieved by Russian scholars, far from being inferior to those of their foreign counterparts, are in some cases actually better. According to Western analysts, in terms of the amount of nanotechnology research we are behind the United States and Japan, but ahead of most countries in Europe, America, and the Asia-Pacific Region, including China which draws nourishment to a fairly large extent from Russia's research potential. We can also boast major breakthroughs in nanotechnology commercialization. For example, under the Federal Target Program "Research and Development in Priority Areas of Science and Technology Progress for the Period of 2002-2006" there have been implemented a whole series of most important innovation projects, which constitute a mechanism of public-private partnership in developing nanotechnology-related priority sectors in various sciences and industries, among them production of instruments and equipment for nanotechnologies (under the Nanoequipment innovation project). Work on the project is expected to secure for Russia a leading position in the world market of nanotechnology equipment.

By now, we have started production of universal nanotechnology complexes for researching and modifying surface nanostructures in flow and gaseous media, for optimizing the synthesis of polymers and biological specimens, and for producing microelectronic components, including metering equipment based on a combination of scanning probe microscopy and laser spectroscopy; technologies have been devised and batch production is about to start of new-generation sealing and fire-proof materials for general industrial use (under the Sealing and Fire-proof Composites innovative project); employment of the products created under this project gives the following advantages: it reduces expenditure of fuel and energy resources by eliminating leakages in split and all-in-one hermetically sealed units; it reduces 1.5 to 2.4 times the steel intensity of locking and regulating fittings; it increases five to eight times the time between repairs while operating the technological equipment; it reduces five to ten times the cost of repairs and part replacement thanks to their greater service life. There has appeared a fundamentally new resource- and energy-saving technique of hydrocarbon processing, including utilization of oil-well gases on the basis of nanoporous catalyst structures (within the framework of the Catalyst Nanomembranes innovative project). Using such membranes will help reduce to one third the amount of carbon dioxide atmospheric emissions.

Because at the moment Russia in unable, for a variety of reasons, to conduct research within every nanotechnology development trend, it is necessary to name priority tasks.

- Task one is resource consolidation at breakthrough R&D sectors in nanotechnologies and nanomaterials, and improved efficiency of government spending on the R&D.
- Task two is to form a world-level instrument base for R&D in the area of nanotechnologies and nanomaterials, systematic provision of instruments for the national nanotechnology network. These problems can be addressed under the Federal Target Program "Infrastructure Development for the Nanoindustry in the Russian Federation for the period of 2008-2015."

The total amount of money to be earmarked for the Program exceeds 29 billion rubles, with more than 28 billion coming from the federal budget.

Program implementation may run up against the following hurdles: lack of enthusiasm on the part of private business for introducing nanotechnologies and nanomaterials in production, because the nanotechnology industry is only just beginning to emerge, which accounts for higher risks as compared to other knowledge-intensive industries; the need to create from scratch many market segments for nanoindustry development.

In order to successfully use in practice modern science-and-technology achievements, and for Russia's **defense industry enterprises** to manufacture competitive products on a large scale (armaments, military and specialized hardware), we should first of all possess cutting-edge ***production technologies***. Production equipment should rely heavily on electronics, means of flexible automation and control-diagnostic systems, while the share of manual work should be going down steadily.[4] And this can never be achieved unless domestic machine-building receives a boost, thus also stimulating other industries.

In conclusion I would like to emphasize the following three major points.

- **One**. The principles of science-and-technology policies with regard to defense industry enterprises should be based on a combination of the design and institutional approaches.

  Science and technology in Russia's defense-industrial complex cannot be properly furthered unless the following three conditions have been observed.

  – ***First,*** mobilize resources needed for real advancement of defense industry enterprises' technological progress along the chosen priority lines. The list of priority (critical) technologies and projects serving this end must be fairly limited, to prevent resource scattering.

  – ***Second,*** draw up organization and legal rules to involve research and financial resources of private companies (venture funding) in developing and financing the relevant R&D trends in the area of armaments, military and specialized hardware.

  – ***Third,*** the purpose and tasks of managing the science-and-technology development of the defense-industrial complex should typically match the actual priorities of economic entities in the chosen and neighboring economic sectors. Otherwise the obtained set of priority technologies will remain unclaimed by the real participants of the science-and-technology process.

- **Two**. Handling the science-and-technology development of Russia's defense-industrial complex should combine three components – project implementation (funded both from the public purse and on the basis of public-private partnership); creation of supporting infrastructure; formation of the institutional environment. The relative weight of each component is determined largely by the separation of interest subjects and spheres, and also of the responsibility spheres of the state and business entities, including in measuring the gap in development priorities of the country at large and of its defense-industrial complex in particular, as seen by the state and business corporations.
- **Three**. Some foreign gurus are confident that to attain competitive advantages it is all right to resort to unlawful methods, as these are used everywhere, and Western chastising is normally countered with this: You blame us because you wish to keep your monopoly position. To quote Konosuke Matsushita's apt quip, "You in the West commit two mortal sins – you are looking for what has already been found, and you purchase what can be had for nothing."

NOTES:

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