What Impedes Universities from Creating Dual-Purpose Technologies?

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Abstract

Modern universities play a significant role, and in some countries, a critical role in research and development (R&D) on a wide variety of topics, often they concern national security. US university science is an illustrative example in this regard, it is an important source of knowledge and technology for military departments and its industrial counterparts. However, even with the large number of theoretical and empirical studies focusing on different aspects of university research innovation activities, so far, the problems of the development of military or dual-use technologies by universities has been poorly covered in economic literature.

In this article, the specifics of university science participation in defense research and development is examined using the example of the Russian higher education institutes. It is shown that Russian universities are poorly involved in defense-related activities. Based on data from a sample survey of 80 universities, and the analysis of certain public policies on science and innovation, the authors concluded that higher education institutions have considerable potential for performing R&D activities for the defense industry. The actual problems and obstacles impeding the development of university research activities in the interests of the defense industry are identified, including the traditional focus of industrial companies on their own research divisions and sectoral research institutes and design bureaus, weak information about the current opportunities and achievements of university science, and the inadequate activity of universities in promoting their own research competencies and an image of advanced R&D centers. Possible ways of solving the existing problems are put forward for consideration.

Keywords: higher education; university science; research and development; dual-purpose technology; university-industry collaboration; defense industry; science and technology priorities

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Universities play an increasingly important role in supporting national economies' competitiveness by efficiently combining educational, research[1], and entrepreneurial activities. They not only train specialists, create, preserve, and transfer knowledge, but also actively establish innovative companies, develop and implement new technologies, and contribute to economic growth [*Etzkowitz et al.,* 2000; *Etzkowitz,* 2003].

Over the previous two decades, the role of educational organizations as a source of technologies for the market has steadily grown in developed countries [*Henderson et al.,* 1998; *Caloghirou et al.,* 2004; etc.]. According to the Triple Helix model, knowledge-based economic growth is fuelled by universities' cooperation with industry and the state [*Etzkowitz, Leydesdorff,* 1995, 2000; *Etzkowitz,* 2003]. Furthermore, the current "hybrid" configuration of the Triple Helix model (it is the third such model, following the "etatistic" and "laissez-faire" varieties) sees universities as the core and as the main drivers of innovative activities [*Etzkowitz, Leydesdorff,* 2000; *Etzkowitz et al.,* 2000; *Abd Razak, White,* 2015][2].

A key area for implementing the higher education sphere's research and innovation potential is the creation of knowledge, products, and technologies initially designed for security and defense purposes, or with the potential for special- or dual-purpose application. The US experience is particularly revealing, where universities annually receive between 10% and 13% of the Department of Defense's (DoD) total research and development (R&D) appropriations [*Pankova,* 2016]. Evidence of the military agency's increased attention to universities' research capabilities is the application of funding tools designed exclusively for these organizations. For example, the objective of the DURIP program (Defense University Research Instrumentation Program) is to provide them with the equipment they need to execute DoD orders.[3] The MURI program (Multidisciplinary University Research Initiatives Program) provides funding for multidisciplinary university research whose results, in addition to defense-related applications, also have market potential[4].

The US universities' contribution to the country's defense is not limited to executing direct orders for military and dual-purpose R&D. Twelve University Affiliated Research Centers (UARCs) are operating in the US, plus two Federally Funded Research and Development Centers (FFRDCs) also run by universities and regularly funded by the defense department[5].

The US Defense Advanced Research Projects Agency (DARPA) pays considerable attention to strengthening partnerships with universities covering a wide range of areas from basic research to applied development. The agency's mandate includes identifying university projects with no apparent military or commercial applications, but with significant potential for practical implementation. DARPA funds basic and applied research by companies, universities, and non-governmental R&D organizations, promotes cooperation between universities and businesses, the discussion of promising ideas, and the creation of relevant communities [*Popova,* 2010; *Pankova,* 2016; DARPA, 2016].

A number of theoretical and empirical studies of various aspects of universities' research and innovation activities have been published, including their cooperation with companies [*Clark,* 1998; *Meyer-Krahmer, Schmoch,* 1998; *Etzkowitz et al.,* 2000; *Siegel,* 2003; *D'Este, Patel,* 2007; *Perkmann, Walsh,* 2007; etc.]. However, no detailed studies of defense-oriented research have yet been conducted. Scientists do touch upon this subject while analyzing the activities of defense agencies and services cooperating with universities, such as DARPA or the UK's Defence Evaluation and Research Agency (DERA), but beyond noting the fact of such partnerships, authors do not provide a detailed analysis of relevant issues [*Molas-Gallart, Sinclair,* 1999; *Popova,* 2010].

A specific feature of the Russian research sector inherited from the Soviet period is the domination of "conventional" R&D organizations such as institutes of the state academies of sciences, and research institutes and design bureaus administered by various government ministries. The role of universities in this sphere traditionally was, and remains, quite modest. For example, in 2015, the higher education sector's share of the country's gross domestic expenditures on R&D (GERD) was less than 10%, and they employed about 12% of all Russian researchers. Still, the importance of university science did grow, especially during the 2008–2011 post-recession recovery (Figure 1). The government tried to learn from the lessons of the crisis and promote economic growth of a "new kind", thus encouraging universities' activities de facto became a major priority of the science, technology, and innovation (STI) policy [*Kuzyk, Simachev,* 2013].

Compared with 2000, the higher education sector's share of total GERD has more than doubled (Figure 2). Still, in this regard Russia remains far behind not only the countries that traditionally adhere to the university-based R&D model, but even behind some of the former socialist countries and Soviet republics [*Gokhberg et al.,* 2009; *Gokhberg, Kuznetsova,* 2011]. Russian universities' R&D cooperation with businesses does not look very impressive either (Figure 2).

However, the current Russian situation with universities' research and innovation activities is not at all unique. Many former Soviet republics and socialist states are in the same position, with universities'

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[1] In the middle of the 20th century, the prevailing view of universities was as "pure science" actors at the source of scientific progress [*Gertner,* 2013; *Hirschi,* 2013].

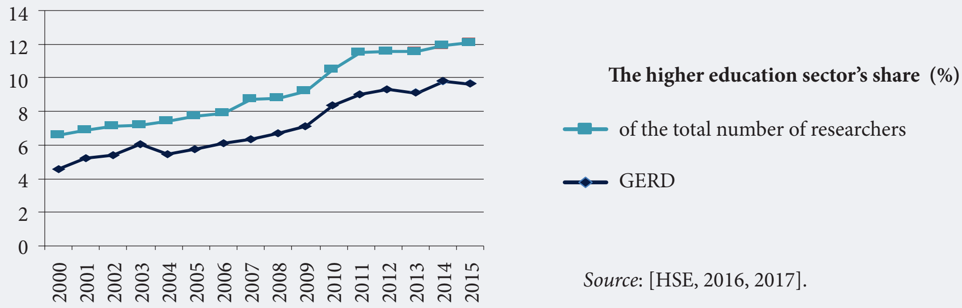
[2] The main thesis of the Triple Helix theory is that knowledge creation institutions dominate the innovation system, and in many countries, universities are believed to be the most important of these [*Dezhina, Kiseleva,* 2007].

[3] See: https://www.onr.navy.mil/Science-Technology/Directorates/office-research-discovery-invention/Sponsored-Research/University-Research-Initiatives/DURIP for more (last accessed on 14.11.2017).

[4] See: https://www.onr.navy.mil/Science-Technology/Directorates/office-research-discovery-invention/Sponsored-Research/University-Research-Initiatives/MURI for more (last accessed on 14.11.2017).

[5] See: https://www.nsf.gov/statistics/ffrdclist/ for more (last accessed on 14.11.2017).

Figure 1. **Relative Indicators of Universities' Research Activities in 2000–2015**



Source: [HSE, 2016, 2017].

research remaining secondary compared with that of "major league" players, i.e., specialized institutes and laboratories [*Glänzel, Schlemmer,* 2007; *Altbach et al.,* 2009]. A similar picture can be observed in a number of Western European countries (Italy, Spain, Portugal), Latin America (Argentina, Chile, Mexico, Brazil, Columbia), and South-East Asia (Thailand, Philippines), etc. (Figure 3)

This paper analyzes specifically Russian features of higher education organizations' participation in military, special- and dual-purpose R&D in the present-day context. The scale of such activities is estimated, along with universities' willingness to step them up, the availability of required capabilities and competencies, and the limiting factors. Recommendations are put foward to increase universities' contributions to the development of the defense industry, and of the industrial sector in general.

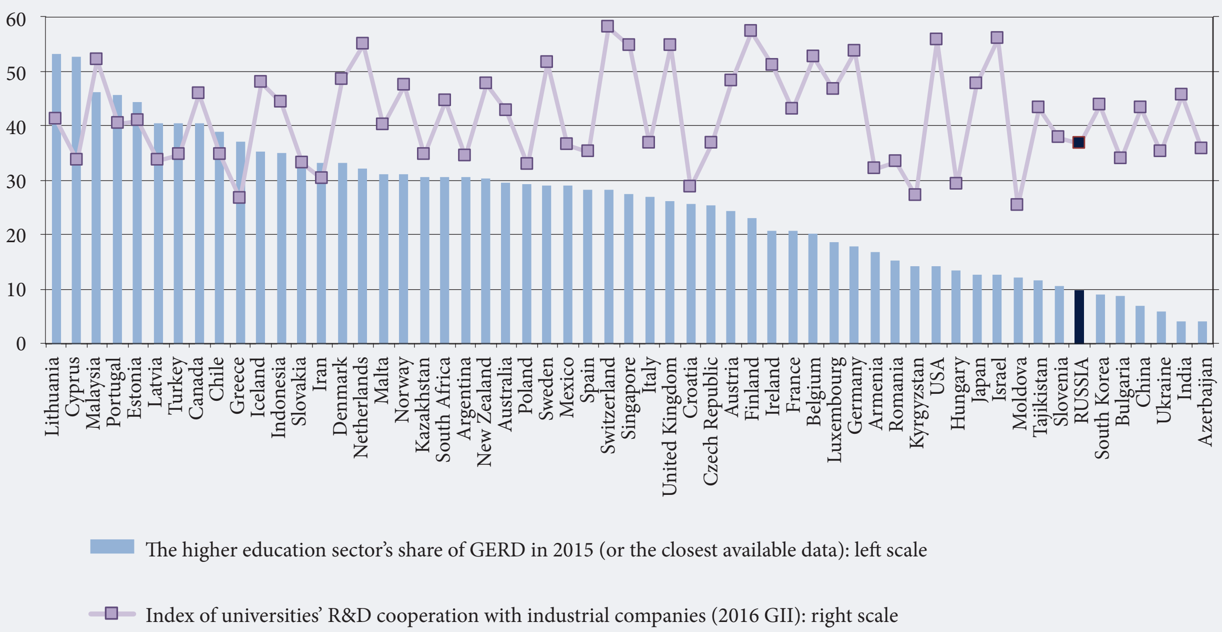
Universities' Potential and Scope of Participating in Defense and Dual-Purpose R&D

Defense R&D

Defense-related R&D is a quite large and promising area. According to open source data, relevant expenditures rapidly grew during over the last few years (Figure 4). For example, in 2015, R&D funding allocated as part of state defense order has more than doubled compared with 2012 (122% average annual growth). To compare, budget appropriations for civil R&D during the same period grew by less than a quarter (average annual growth 109%).

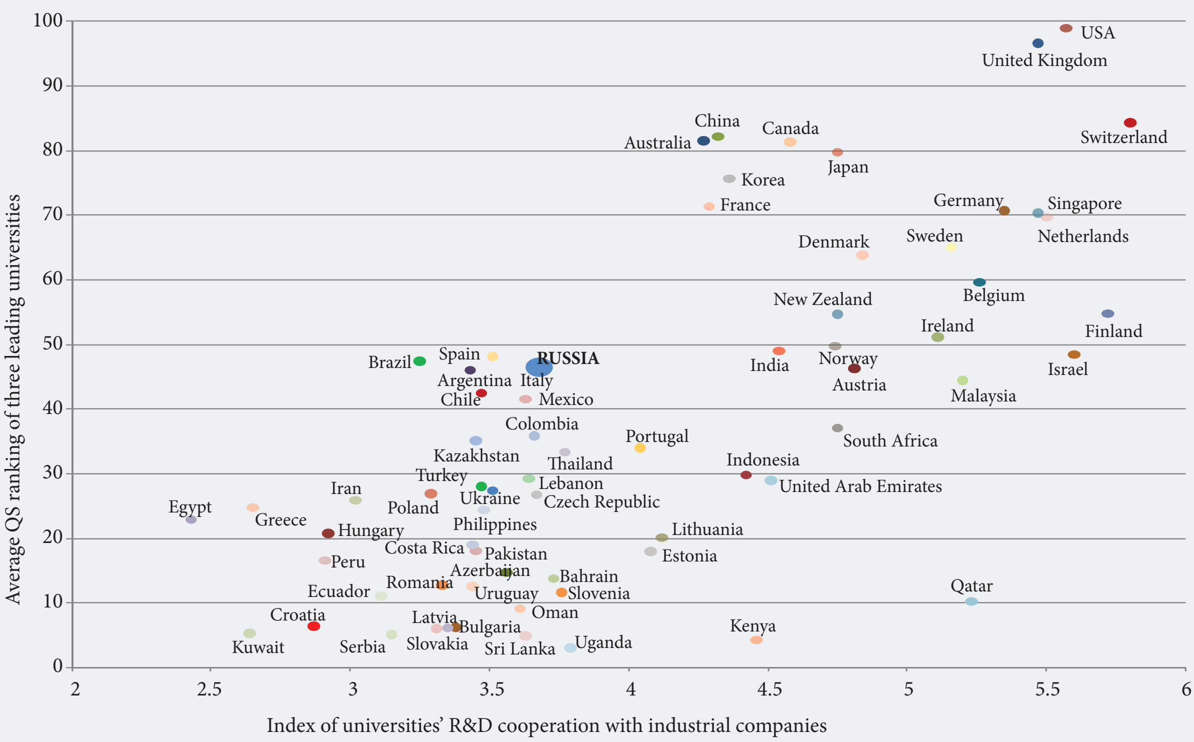
No statistics are available on Russian universities' defense-related R&D. Nevertheless, the available data allows one to estimate the share of universities' R&D in priority S&T development areas for Russia that

Figure 2. **Universities' Research Activities: An International Comparison**



Sources: [HSE, 2017; Cornell University et al., 2017].

Figure 3. **The University Sector's Indicators and Cooperation with Industrial Companies: 2016**



Sources: composed by the authors on the basis of [WEF, 2016; Cornell University et al., 2017].

fall outside the scope of civil segments.[6] The relevant figure is quite small (about 10% in 2015), and shows no pronounced growth (at least not over the previous decade) (Figure 5).

A survey of R&D and higher education organizations conducted by the Interdepartmental Analytical Center (IAC) in 2012[7] provides a general idea about the extent of universities' involvement in defense-related R&D.

Universities participated in R&D in civil priority S&T development areas more actively than "mainstream" R&D organizations did. However, in the defense and national security domain, the situation was quite different: 16% of the surveyed R&D organizations conducted such research, compared with just 7% of universities. Note that the "most defense-related" priority area – advanced weapon, military, and special technology – turns out to be the least represented, with only 2% of the universities in the sample conducting such research. On the contrary, it was one of the most popular research areas for R&D organizations: 13% of the surveyed research institutes conducted relevant research (Figure 6).

According to IAC experts, total expenditures on defense-related R&D conducted by higher education and research organizations supervised by the Russian Ministry of Education and Science on the basis of direct contracts with the Russian Ministry of Defense in 2015 amounted to just about 200 million rubles, or less than 0.1% of the overall volume of public R&D in the state defense order. To compare, US universities get at least 10% of the DoD's R&D expenditures. It should be kept in mind though that the most common format of involving universities in defense R&D in Russia is through procurement orders placed not directly by the Ministry of Defense but by various defense industry companies and their integrated structures (the reasons for this arrangement will be discussed below). Even so, according to the IAC, such companies' expenditures in 2015 amounted to only about 3 billion rubles (out of that 2.3 billion went directly to universities, and about 700 million to engineering centers established by them), or just over 1% of R&D conducted in the framework of state defense order.

Thus, Russian universities remain poorly involved in defense-related R&D due to their low levels of related activity and specific features of public defense-related procurement (see below).

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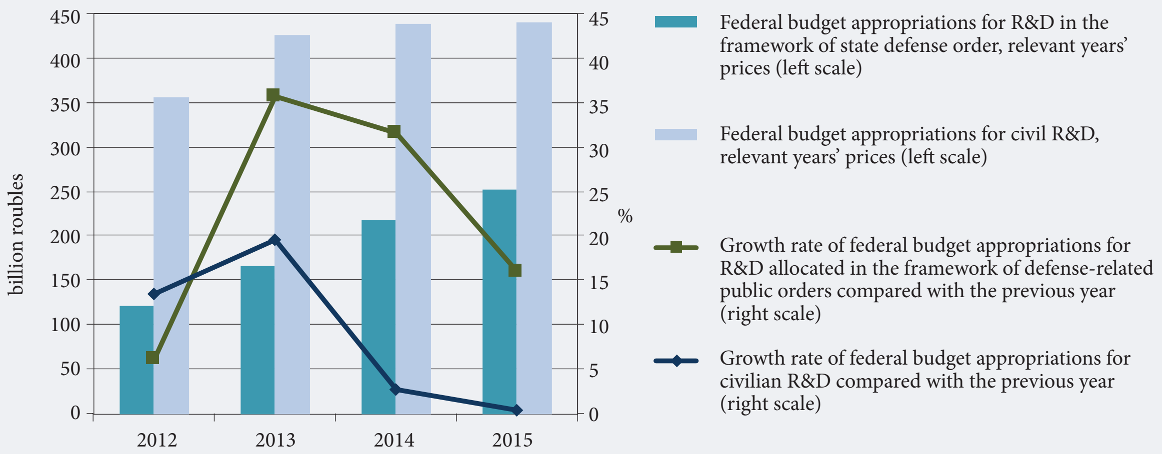
[6] Out of the nine priority S&T development areas approved by the President of Russia (Executive order No. 899 of July 7, 2011), six can be notionally classified as civil: nanosystems; information and telecommunication systems; life sciences; efficient environmental management; transport and space systems; energy efficiency and energy saving; and nuclear energy. The other three priority areas belong in the national security and defense domain: security and counterterrorism; advanced weapon, military, and special technology; military, special- and dual-purpose robotic complexes (systems).

[7] The survey was conducted in 2012 by the IAC with support of the HSE Institute for Statistical Studies and Economics of Knowledge Centre for Business Trend Studies and the Information and Publishing Center "Statistics of Russia". The heads of Russian R&D and higher education organizations were surveyed using a formalized questionnaire specially designed by the IAC. The total sample included 361 R&D organizations: 109 universities and 252 research institutes (for more about the survey and its results see, e.g., [*Simachev et al.*, 2015]).

Figure 4. **Growth of Federal Budget Appropriations for Civilian and Military R&D**



Sources: [*Frolov*, 2016; HSE, 2017], authors' calculations.

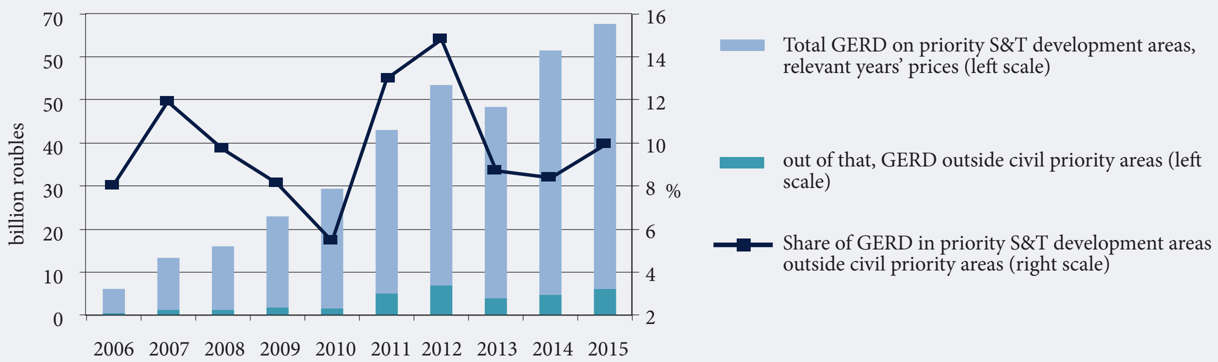
Dual-purpose R&D

The aforementioned situation regarding universities' poor involvement in defense-related R&D raises a question about their ability to make a more significant contribution in this area, i.e., the availability of the relevant S&T groundwork results and competencies.

In late 2016–early 2017, IAC experts conducted an integrated sample assessment of 80 Russian universities' potential to perform defense-related R&D. The selected universities were interested in such work and in cooperating with the Ministry of Defense.[8] Having such an interest was used as university selection criterion, as opposed to having relevant practical experience. This allowed for focusing on universities willing carry out defense-related R&D and develop relevant competencies, but still lacking close ties with the Ministry of Defense. Universities that did not see defense-related areas as research priorities have not been considered. The main sources of data for the integrated assessment included a questionnaire-based survey and in-depth interviews. They were conducted in 2016 covering 80 and 11 universities, respectively. Universities' potential to conduct R&D for industrial production purposes was analyzed (or their capability to build one quickly); competitiveness in the relevant subject areas; and experience working for the defense industry, including the execution of procurement orders placed by defense companies. The respondents were rectors (vice-rectors) and the heads of relevant university departments.

Also, the following additional data sources were used:

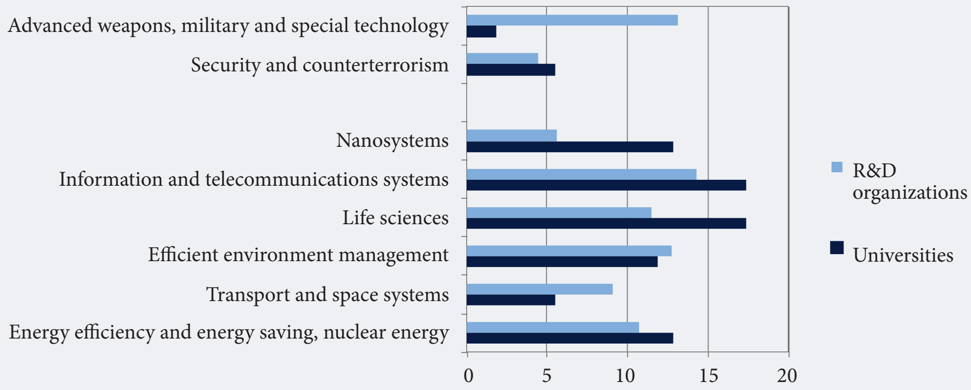
Figure 5. **GERD on Priority S&T Development Areas**



Sources: [HSE, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017], authors' calculations.

[8] The following indicators were used to detect universities' interest in stepping up R&D cooperation with the Russian Ministry of Defense: official documents signed by management (letters, etc.); the appointment of an official to coordinate such cooperation; making one or more university departments officially responsible for carrying out R&D for the Russian Ministry of Defense.

Figure 6. **Participation of Research Institutes and Universities in R&D in Priority S&T Development Areas in 2012** (*%, as indicated by heads of the surveyed organisations*)



Source: IAAC, results of a sample survey of R&D organisations, 2012.

- approved university strategies and programs as well as other documents published on their official websites;
- innovation development programs of defense industry companies cooperating with universities;
- presentations and reports by university and defense industry company officials at public events such as conferences, workshops, round table discussions, etc.

The main limitation of the applied research methodology was due to the fact that most of the data used to carry out the analysis originated at the very universities being analyzed. Since all of them had expressed their interest in stepping up defense-related R&D and cooperation with the Ministry of Defense, a certain bias was inevitable: excessive optimism regarding their R&D potential and competitiveness. However, since the documents of the industrial companies were also used along with the university sources, it allowed us to significantly reduce the partiality of the assessments.

It has turned out that almost a half of the surveyed universities (45%), despite their interest in cooperating with the Ministry of Defense, were conducting no R&D in national security- or defense-related S&T fields.[9] The ones that did have such experience in most cases specialized in designing military, special- and dual-purpose robotic systems and complexes (48%), and less often conducted research in security and counterterrorism (29%) and advanced weapons, military, and special technology (23%).

Notably, the scope for cooperation between universities and the Ministry of Defense and defense industry companies was not limited to national security and defense-related priority S&T areas as such. Therefore, in order to assess universities' potential to carry out relevant R&D, a more extensive list must be used[10].

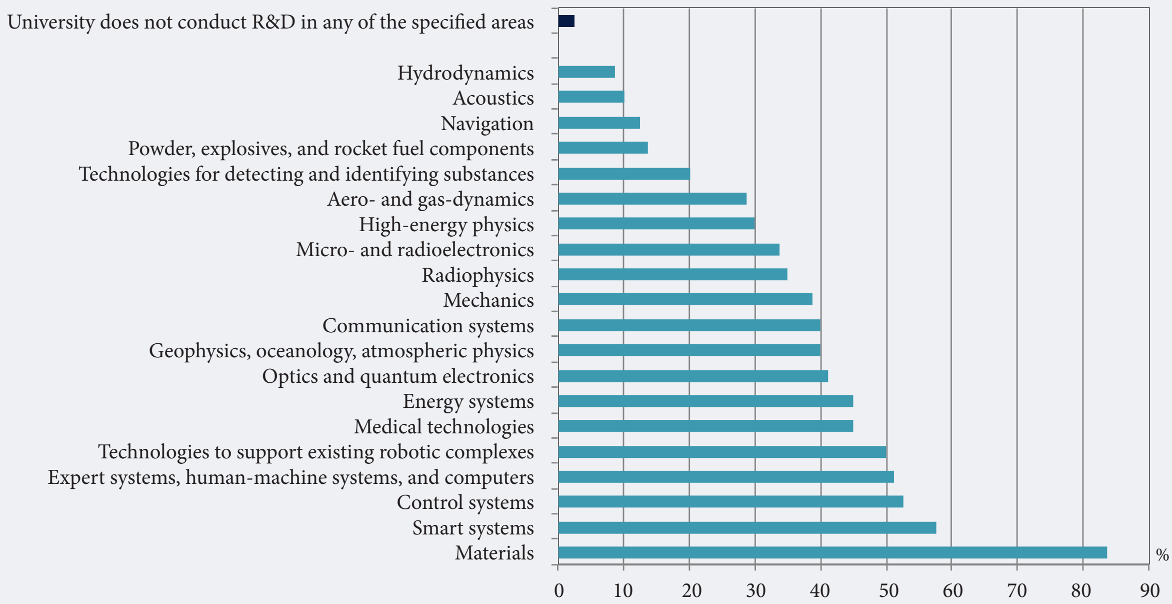
The vast majority (97%) of the surveyed universities did have groundwork results and competencies in the abovementioned areas (as a rule, in several). Twenty-five percent of them had experience in at least half of the research fields of interest to the Ministry of Defense. Most often universities conducted R&D in such fields as materials, smart systems, control systems, expert and human-machine systems, and support technologies for robotic complexes (Figure 7)

Thus, despite their relatively modest involvement in R&D in defense-related areas as such, universities actively conduct research in other areas of interest to the Ministry of Defense. Particularly important is the issue of the level of universities' R&D, and of the solutions they propose. It should be noted that higher education organizations are well represented on Russian technology platforms, a significant share of which (more than 60%) belong in subject areas important for the Ministry of Defense. Many universities (MSU, MSTU, MIPT, MEPhI, MAI, MISIS, TUSUR, FEFU, HSE, etc.) are key participants on relevant platforms, and in projects implemented for the state and various businesses. More than a half of the projects for developing high technologies implemented jointly by companies and universities with public support provided in the scope of the RF Government Regulation No. 218 of 09.04.2010 *de facto* had dual purposes, or at least were related to research areas important to the Ministry of Defense. Their results in most cases were assessed favorably, and not just on the basis of direct indicators such as the development and application of research-intensive products, but also in terms of building research competencies and skills required for cooperating with businesses [*Dezhina, Simachev,* 2013; Inconsult K, Ltd. *et al.*, 2015].

[9] Similar results were obtained in the framework of a questionnaire-based survey of 153 Russian universities conducted by the Scientific Research Institute – Federal Research Centre for Projects Evaluation and Consulting Services (SRI FRCEC): 49% of the universities had no experience of carrying out national security and defense projects, nor have ever been proposed to do so; another 11% of the respondents, despite lacking relevant experience, still have been commissioned to conduct R&D in these areas [*Epishin et al.,* 2016].

[10] The corresponding list has been approved by the specialized subdivision of the Ministry of Defense of Russia as the main activities of the Center for Support of Initiative Development and Innovation. This list is open, moreover, one of the aims of its compilation is to inform the scientific community about the directions of research and innovation activities that correspond to the interests of the Ministry of Defense. Currently, the list includes 20 items presented in Figure 7.

Figure 7. **Universities' R&D in Priority Areas of Interest to the Russian Ministry of Defense**
(% of the surveyed universities)



Source: IAC – results of the sample integrated assessment of universities, 2017.

About a half of the engineering centers established by universities have the necessary competencies and advanced equipment required for conducting defense-related or dual-purpose research, and practical experience executing defense industry companies' procurement orders. Businesses' demand for their services is also growing [Minobrnauki Rossii, Minpromtorg Rossii, 2017]. Universities actively cooperate with the Advanced Research Foundation, which provides support for high-risk R&D aimed at obtaining breakthrough results in military hardware and technological development, the socioeconomic sphere, the development of innovative technologies, and the production of high-tech products for military, special, or dual purposes.[11] Several leading universities, such as MIPT, TUSUR, SSAU, SUAI, VlSU, and MAI, won the foundation's tenders for designing prototype technologies. The foundation established joint research laboratories with MSU, UNN, and SFedU. This gives ground to conclude that many of the universities willing to conduct defense-related, special- and dual-purpose R&D do indeed have the required groundwork results and competences.

Issues Associated with Universities' Participation in Defense-Related R&D

The current contradiction between universities' poor involvement in government-commissioned defense-related R&D and their potential in this field is due to a number of issues with the state defense order's specific features and procedures for its placement as well as with certain characteristics of the universities and defense industry companies themselves.

First of all, most universities simply do not meet the numerous requirements set by the government for state defense order general contractors, such as:

- having a special bank account for making payments to other project participants;
- separate accounting for each contract signed in the framework scope of state defense order;
- providing financial securities for executing state defense order contracts;
- ensuring that the developed products meet special requirements.

In a number of cases, special licences are required (to design weapons and military equipment, ammunition, pyrotechnic products), as well as clearance to access state secrets. In addition, it is usually necessary to make and field-test prototypes, etc. Keeping all this in mind, few universities can act as general contractors executing state defense order. Only 20% of the universities included in our sample fully met the above requirements[12].

Note that the model of a university's role as a state defense order principal contractor does not fit all universities, not by far. Only a few of the technological universities with access to relevant resources, competencies, and capabilities can meet the relevant standards. To others, executing specific orders by

[11] Due to the specific features of the foundation's activities it is frequently compared with DARPA [*Eremenko,* 2013; etc.].

[12] In the case of designing weapons, a lack of relevant licenses comes to the foreground. The aforementioned survey conducted by the SRI FRCEC revealed that only 7% of universities had such licenses (18% of those who had worked with the Russian Ministry of Defense previously), and 3% were in the process of acquiring them [*Epishin et al.,* 2016].

defense industry companies and their integrated structures seems to be the best format for taking part in defense-related R&D. However, the level of universities' cooperation with the defense industry (and with industrial companies generally, for that matter) still remains low. According to a survey of Russian universities conducted by the IAC in 2015[13], most of them do perform R&D commissioned by industrial companies, but only for about a quarter of universities does the share of such R&D projects exceeds 50% of the total.

The reasons of Russian universities' relatively poor cooperation with industrial enterprises has been repeatedly discussed in earlier works (see, e.g., [*Simachev et al.,* 2014]), so we will concentrate on the factors and issues relevant to their cooperation with the defense industry. In most cases, defense-related R&D is commissioned by large public companies, holdings, and concerns. Such companies tend to have their own R&D and design organizations or departments, which obviously have the best chance to obtain such work. Also, large companies specializing in defense (and in other industries as well) usually have an established system of production partnerships and contacts, first of all with leading R&D organizations active in relevant research fields, so when they place orders they tend to go to their tried and true partners first [*Simachev et al.,* 2014]. Most of the universities do not belong within the "established circle" of defense industry companies' production partners, so they by default have a smaller chance to winning procurement contracts, even if they do have advanced groundwork results and competencies in the R&D and design fields.

In reality, mainly the universities that have close ties with defense industry companies (or are located in their vicinity) usually get orders from them. Accordingly, they can successively cooperate with these companies even in related areas such as:

- staff training;
- participation in joint civil research projects, including projects supported by the Russian Ministry of Education and Science;
- offering the services of universities' engineering centers and shared research equipment centers;
- cooperation in the framework of technology platforms or innovative territorial clusters.

In some cases, involving universities in executing public defense orders as co-contractors can be a logical extension of such cooperation.

Another serious barrier hindering universities' participation in defense-related R&D is their image as exclusively educational organizations, not advanced research competency centers capable of professionally executing complex orders. This is due to the insufficient level of universities' activities in relevant R&D areas, i.e., those matching state defense order. Note that it is not so much the actual R&D performed by the universities as their public perception, i.e., coverage in media and the promotion of results.[14] This is also evidence of insufficiently productive efforts that the government is making to step up universities' research and innovation potential.

At the same time, it would not be correct to say that the lack of companies' trust in universities as reliable performers of R&D is exclusively due to the established stereotypes about academia and insufficient information about its potential. In particular, the results of surveys covering 400 state universities conducted by the HSE Institute for Statistical Studies and Economics of Knowledge indicate that fewer than 10% of state universities can be included in the group of education and research leaders capable of advancing science and integrating research and educational activities [*Abankina et al.,* 2013]. Universities' inadequate focus on meeting consumers' needs, and the poor competitiveness of the solutions they offer come to the foreground [*Simachev et al.,* 2014; *Gershman et al.,* 2015]. Thus, the opportunities for promoting universities' participation in defense-related R&D amount not only to stepping up their contacts and cooperation with defense industry companies, but also to improving their own internal arrangements, first of all bringing the R&D areas they specialize in closer to the sector's actual demand.

Conclusions and Recommendations

Modern universities actively participate in research and innovation activities and show interest in security- and defense-related areas. In the US, UK, China, and other countries, they play a significant role in researching and developing special- and dual-purpose technologies. In Russia, the level of universities' R&D activities generally remains quite low, which is one of the reasons of their poor involvement in defense-related R&D. However, given the strong demand for such research funded through state defense order, this area of universities' R&D activities seems to offer very good prospects.

We did not confine ourselves to a narrow interpretation of defense R&D as activities aimed at supporting national security and designing weapons, military, and special-purpose hardware, so having analyzed universities' results in a wide range of fields, we concluded that they have great potential for conducting such research.

However, universities' cooperation with industrial companies (including defense industry ones) remains rather weak, and in most cases, tends to be inertial and locally limited. Companies' (and their integrated structures') choice of R&D contractors seems to be inclined towards their own R&D departments or subsidiaries, or established partners, usually the sectoral research institutes and design bureaus. The low

[13] The survey was conducted in the autumn of 2015; university heads were asked to fill in specially designed questionnaires. 151 universities were included in the final sample.

[14] The lack of information about promising R&D results as a factor hindering cooperation between science and industry is generally recognized by businesses and R&D organizations alike [*Simachev et al.,* 2014].

level of universities' participation in such work can be partially explained by companies' insufficient awareness of their actual potential, abilities, and achievements. Another reason is the sceptical attitude towards universities' ability to adequately execute complex R&D orders, which is quite typical for businesses and not infrequently based on their previous experiences.

Promoting the defense industry's demand for university R&D services would require a significant effort, first of all, by the universities themselves. They should work on their image, so that they would be perceived not as solely educational organizations but as research and development centers as well, and furthermore should advertise their relevant abilities, competencies, and achievements among potential customers. Conventional promotion techniques of this kind include publications, patenting, and training expert personnel. It is also important to participate in federal- and regional-level coordination and consulting bodies, expert councils, working groups, and other venues related to the defense industry. Establishing contacts and extending cooperation with potential customers via various communication and collaboration arrangements (such as technology platforms, clusters, etc.) also appears to be an effective tool.

Many universities will have to pay more attention to meeting companies' actual demands, and not just in terms of identifying relevant R&D areas but also regarding arrangements and formats for the transfer and practical application of research results. The latter may require making certain organizational changes and applying innovative approaches such as setting up project teams comprised of staff from various university departments and the customers' representatives. Businesses often prefer to deal with R&D providers not on the level of the whole organization but with specific staff members or divisions. Many universities see this as a problem hindering "normal" cooperation [*Simachev et al.,* 2014]. Meanwhile, strengthening cooperation between industry and science requires that universities do not obstruct but promote the establishment of direct contacts between companies and research teams, both formal (laboratories, sections, etc.) and informal, as well as specific researchers and experts alike, for example, by publishing relevant information on the university website, in printed documents, presenting them at meetings, etc.

Cooperation between universities and defense industry companies can and should involve the active participation of the sectoral research institutes and design bureaus. Since the latter may see universities as competition, universities must offer the sectoral R&D organizations a mutually beneficial cooperation format.

Universities usually have a wider range of specialization areas than large research institutes do, so they can help the latter with conducting research, providing consulting and other services in less familiar fields. Given that universities have S&T competencies in various areas, they can transfer advanced technologies between the military and civilian sectors more efficiently than the defense industry's own research institutes. Universities' research and innovation infrastructural facilities, created with public support, such as engineering, shared research equipment, technology transfer centers, etc., can serve as a key tool for strengthening the partnership between universities, academic institutes, and companies. The dynamic developments in a number of industries triggered by digitalization, human-machine and machine-to-machine communication, advanced manufacturing technologies, etc., have opened new opportunities for such cooperation. In a situation of major technological transformations, leading universities can not only provide local services to companies, but act as catalysts of change by offering companies advanced technologies and solutions in the framework of "search network" especially designed for these purposes.

No less important is the position of the other side, i.e., the businesses. Previous studies show that strengthening universities' and research organizations' partnerships with companies is hindered by the latter's insufficient openness to innovation. Thus, stepping up this cooperation would involve promoting not only the supply of, but also demand for innovations.

In the aforementioned situation, the role of the state becomes crucial: it must create favorable conditions and incentives for effective cooperation between universities and industry [*Etzkowitz, Leydesdorff,* 2000; *Tether, Tajar,* 2008]. In particular, information exchanges between them in a mutually beneficial format should be encouraged (at least on the basis of the existing interactive information systems). As to businesses' low level of interest in innovation, there is no universal recipe for overcoming this hurdle quickly and irreversibly. Practice shows that administrative and directive steps do not work very well in this regard. Certain tax incentives, changes of technological regulations and standards encouraging the application of new products, technologies, and equipment and abandoning old ones seem to have a significant positive effect on the level of innovativeness for the whole industry or its specific segments (at least in terms of the number of enterprises involved) [*Ivanov et al.,* 2012]. Providing financial support makes the largest contribution to promoting separate Russian companies' innovation activities [*Simachev et al.,* 2017]. Therefore, it is important to extend the practices of public participation in funding the research universities conduct for businesses, and it is also critical implement joint innovative projects. As was noted, it encourages the establishment of partnerships between universities and defense industry companies in the military and civil sectors alike. Implementing civil and military projects in parallel with one another could lead to the convergence of and mutual penetration in relevant subject areas, help obtain breakthrough results, and propose new, promising scientific and technological areas.

S&T development priorities may play a major role in encouraging universities to conduct defense-related and dual-purpose R&D. Identifying relevant focus areas for cooperation between universities, research organizations, companies, and the state would help concentrate resources and efforts in the R&D areas that would make the greatest contribution to national security. As for universities willing to step up their cooperation with the defense industry, such priorities may serve as a foundation not only for defining their research agendas but also for developing and updating their curricula.

Involving all key actors in priority-setting would allow to take into account their positions and interests, which is critically important for their accepting the priorities as guidelines to be followed, and for promoting communication between the involved parties. This would require coming up with a unified priority-setting methodology based on the following principles:

- focus on accomplishing major national security objectives;
- medium-term planning horizon;
- taking into account national competitive advantages with a focus on their implementation;
- assessing feasibility (the availability of the required resources, S&T groundwork results, etc.);
- planning for the application of specific STI policy tools.

A focus on ensuring national security does not mean that all priority areas and technologies selected for development should be of a distinctly military nature. The convergence of civil and military technologies can provide a major boost for the advancement of science, eliminate the duplication of research areas, and help concentrate resources on accomplishing the most important objectives.

Focus areas for cooperation between universities, research organizations, companies, and the state in the field of defense should match existing national S&T priorities, and fit into the long-term technology foresight system. Particular attention should be paid to relevant implementation mechanisms, specifically to ensure their integration with existing STI and industrial policy tools. The new system of priorities must be flexible, capable of quickly adjusting to emerging developments in S&T, in the defense industry, and in the overall industrial sector. The continuous monitoring of priority implementation would help assess their contribution to accomplishing national security objectives and help to adjust their content and fine-tune implementation mechanisms. The list of priorities should be regularly updated in line with changing S&T development trends.

In conclusion, we would like to stress that the current situation with the research and innovation activities of Russian universities is not unique. Problems with cooperation between universities' research divisions and industrial companies, which have been analyzed for the Russian context, engendered by universities' insufficient entrepreneurial activity, predominantly "educational" image, competition from other organizations that create knowledge and develop technologies, and businesses' poor interest in innovation, are typical for other countries as well [*Davies,* 2001; *Deiaco et al.,* 2008; *Smith et al.,* 2011; *Foss, Gibson, 2015; Oosterbeek et al.,* 2010; *Stensaker, Benner,* 2013]. Accordingly, the proposed recommendations and conclusions apply not only to Russia but also to any country facing the same issues with strengthening universities' research and their cooperation with businesses. Still, national specifics of universities' cooperation with defense industry companies do deserve special attention.

This paper certainly has not covered all relevant aspects of universities' participation in military, special- and dual-purpose R&D. The issue of universities' having the necessary groundwork results, and their competitiveness in the area was analyzed only partially. The effects of the various forms of government support on the scale and productivity of universities' military, special- and dual-purpose R&D and on the effectiveness of their cooperation with defense industry companies deserve a special study. This also applies to universities' partnerships with academic and sectoral research organizations, their role in the inter-sectoral transfer of advanced technologies, and the necessary changes of universities' organizational structure to support successful cooperation with businesses, etc. All these issues seem to serve as promising topics for future research.

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