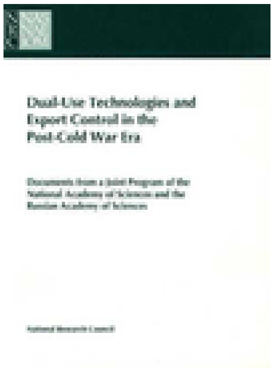

Dual-Use Technologies and Export Control in the Post-Cold War Era

Office of International Affairs, National Research Council

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Dual-Use Technologies and Export Administration in the Post-Cold War Era

Documents from a Joint Program of the National Academy of Sciences and the Russian Academy of Sciences

Office of International Affairs

National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

This publication reports the results of a one-year joint program between the National Academy of Sciences (NAS) and the Russian Academy of Sciences (RAS) on dual-use technologies and export control. The goal of the program has been to define a balance between the conflicting demands of controlling the spread of technology for strategically dangerous armaments while encouraging the spread of technology for economic growth and development.

The program, which ran from December 1991 to December 1992, had its origins in the two major reports on U.S. national security export controls* which the National Academy of Sciences and the National Academy of Engineering prepared in 1987 and 1991, respectively, at the request of the U.S. Congress and a number of executive branch agencies. The more recent efforts of the Commonwealth of Independent States to join Western economic and security regimes created the impetus for this current effort.

With the exception of a joint statement of the NAS and the RAS, the views expressed in this document are those of the individual authors and do not necessarily reflect the positions of either the NAS or the RAS.

The NAS expresses its appreciation to the Russian Academy of Sciences for its cooperation throughout the program. Special thanks are owed to Major General William Bums (retired), leader of the NAS delegation on its exploratory mission to Moscow; Dr. Roland Schmitt, Chairman of the NAS delegation; Academician Gennadiy Mesyats, Chairman of the Russian delegation; Dr. Mitchel B. Wallerstein, former Deputy Executive Officer, National Research Council, and current Deputy Assistant Secretary for Counterproliferation, U.S. Department of Defense; and Mr. Glenn Schweitzer, former Director, Office for Central Europe and Eurasia, National Research Council and current Director of the International Science and Technology Center in Moscow. Financial support from the John D. and Catherine T. MacArthur Foundation is gratefully acknowledged.

* *Finding Common Ground: U.S. Export Controls in a Changed Global Environment*, 1991, and *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition*, 1987, are available from National Academy Press, 2101 Constitution Avenue, Washington, D.C. 20418

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* All documents presented at the December 1992, May 1992, and December 1991 programs were neither approved nor endorsed by the U.S. National Academy of Sciences. The opinions and thoughts presented in these papers are solely those of the authors.

EXECUTIVE SUMMARY

This publication reports the results of a one-year joint program between the National Academy of Sciences (NAS) and the Russian Academy of Sciences (RAS) on dual-use technologies and export control. The program was concerned with the conflicting demands of controlling the spread of proliferation-related technologies, while encouraging the spread of technologies for economic growth and development. It focused particularly on the control of dual-use technologies in and by the Russian Federation, with respect both to internal transfer from civilian to military applications, and to export or re-export to other nations and sub-state actors (including terrorist organizations) seeking to acquire a credible military threat.

During the course of the program, four closely related issues were identified as the principal loci of concern: export administration, defense conversion, brain drain, and the need to sustain Russian science and technology development through additional funding and joint activities.

Consensus on these four issues emerged from three joint meetings over the period December 1991 to December 1992. Each meeting included site visits to dual-use manufacturing facilities in one of the two countries. With the exception of the first meeting, the chairman of the NAS delegations was Dr. Roland Schmitt, President of Rensselaer Polytechnic Institute. The chairman of the RAS delegations throughout the program was Academician Gennadiy Mesyats, Vice President of the Russian Academy of Sciences and Chairman of its Urals Division.

The first interaction took place in Moscow and Perm, Russia, December 13-21, 1991. It sought to determine whether there was sufficient interest and openness on the Russian side to merit initiation of a full-scale joint program. A small delegation of American experts, led by Major General William Burns, former director of the U.S. Arms Control and Disarmament Agency, met with a group of RAS counterparts. Their discussions addressed a variety of issues concerning dual-use technologies, including their application, transfer, and export control. Visiting formerly closed military institutes and factories in Perm and Moscow, the American participants witnessed first-hand the progress and problems of Russian defense conversion as characterized by Russian defense scientists and managers. The visit concluded with a joint protocol of the American and Russian delegations which outlined a list of topics to be addressed over the course of the program. This protocol is included, along with other relevant information from this exploratory meeting, in Appendix 3 of this publication.

Based on this protocol and the success of the exploratory meeting, the NAS and RAS organized a second interaction in Washington, DC, May 26-29, 1992. Members of both delegations presented papers on such topics as: economic aspects of the development and production of dual-use technologies; technology-related industrial reports; categories of manpower having unique knowledge of weapons systems; Russian export control trends; verification schemes; and case studies on the controlled application of dual-use technologies. These papers are included in this publication; the agenda and participants are included in Appendix 2.

The third and final meeting in the program took place in Moscow and St. Petersburg, December 12-20, 1992. It focused on the export control issues surrounding three important technologies with applications in both the civilian and military sectors: advanced materials, optoelectronics, high-speed computing. The NAS delegation included experts in export control as well as the specific technologies discussed. The Russian delegation included key representatives of both the Russian military and scientific communities.

In preparation for the meeting, both Academies commissioned case studies in the three technology areas described above. These case studies are included in the text of this publication. In addition, both delegations prepared a joint statement which was released in April 1993 after endorsement by both Academies and is included here. The joint statement makes recommendations to the governments of the respective academies in three broad areas: access to technologies of proliferation concern, national security concerns, and confidence-building measures.

DUAL-USE TECHNOLOGIES AND EXPORT ADMINISTRATION IN THE POST-COLD WAR ERA

A Joint Statement of the U.S. National Academy of Sciences and the Russian Academy of Sciences

April 1, 1993

JOINT STATEMENT OF THE DELEGATIONS OF THE RAS AND NAS ON DUAL-USE TECHNOLOGIES AND EXPORT ADMINISTRATION

The **Joint Statement of the Delegations of the RAS and NAS on Dual-Use Technologies and Export Administration** is the final product of more than a year of discussions between the Russian Academy of Sciences (formerly the Academy of Sciences of the USSR) and the National Academy of Sciences on this topic. The report was reviewed and approved by both Academies for public release.

PREAMBLE

This report, jointly sponsored by the U.S. National Academy of Sciences (NAS) and the Russian Academy of Sciences (RAS), examines an issue of growing importance and urgency for both countries: the balance between the conflicting demands of controlling the spread of technology for strategically dangerous armaments (SDAs)[1] while encouraging the spread of technology for economic growth and development. Often, it is the same technology that must be both controlled and promoted: the "dual-use" technologies that are applicable to both military and civilian (i.e., commercial) uses. The issue is further compounded by the fact that today much advanced technology is often first used in *civilian* rather than military applications.[2]

The national security interests of the Russian Federation and the United States are also changing. Previously, the principal concern of the United States and the former Soviet Union were the weapons each possessed in large quantities to use against the other. Today, however, there is growing concern in both the United States and the Russian Federation about the proliferation of SDAs among other nations and sub-state actors (including terrorist organizations) seeking to acquire a credible military threat.

The issues advanced in this report are not confined to the interests of the Russian Federation or the United States alone. Nevertheless, we have chosen to begin with these bilateral discussions, convened by the two Academies, as a first step toward a broader interaction. We believe that if we can find common ground for resolving the many conflicting interests in this complex arena, we will have established a sound basis for these broader discussions in the future.

[1] Strategically dangerous armaments (SDAs) is a term introduced at the meeting by General Oleg Rogozin. SDAs include so-called weapons of mass destruction (i.e., nuclear, chemical, and biological weapons), systems for their delivery (including ballistic missiles and advanced strike aircraft), and advanced conventional weapons such as precision-guided munitions (PGMs).

[2] This assertion is justifiable for countries with developed, balanced economies characterized by an excess of supply over demand. However, even in this case the specific requirements of military hardware place the military applications of most technologies in a special category with different price requirements.

Thus, we have adopted the following statement of our intended mission:

To define the issues and recommend solutions—including "confidence-building" measures—to reconcile the following goals:

- to increase technology transfer between the United States and the Russian conversion of Russian defense industries to commercial production in a manner beneficial to both countries; and
- to ensure that technology transfer between the United States and the Russian Federation does not increase the military threat to either country, especially from the export and re-export of technology to countries seeking to acquire SDAs.

It is important to solve this problem, and it is clearly dangerous not to. Yet the probability of *not* solving it is high, because both countries are preoccupied with other, more pressing issues.

The ideal goal is to impose only those constraints on the flow of technology that are necessary for national security, but no more. Economic growth and development are best served by allowing technology to flow freely within the bounds of normal trade, commercial and industrial activities.

INTRODUCTION

Discussions between the U.S. National Academy of Sciences and the Russian Academy of Sciences on the problem of dual-use technologies began with an exploratory planning meeting in December 1991, during which discussions were held in Moscow and a series of site visits were made to dual-use manufacturing enterprises in the city of Perm in the Ural Mountains. In May 1992, a delegation from the RAS visited Washington, DC, to continue the dialogue and to participate in discussions at the NAS headquarters. The RAS delegation also received briefings from U.S. government officials on U.S. export administration measures and expectations for the establishment of Russian export administration measures, and made site visits to dual-use manufacturing enterprises in the Washington-Baltimore area. The final meetings of this first phase of the joint activity took place from December 12-20, 1992, with discussions and site visits in Moscow and St. Petersburg.

During the course of the three meetings, four closely related issues were identified as the principal focus of concern with respect to dual-use technology: export administration, defense conversion, "brain drain," and the need to sustain Russian science and technology development through additional funding and joint activities. Outlined below is an explanation of the basis on which the joint committee discussed each of these issues.

Export Administration

The need for controls on the export between the United States and the Russian Federation of dual-use technologies that are relevant to the development and deployment of SDAs will diminish as relations between the two nations continue to improve and greater levels of trust are established, thereby overcoming the suspicion and threatening actions of the Cold War period. Progress by the Government of the Russian Federation toward the establishment of an adequate export administration system, and its effective enforcement, is therefore vitally important. Ideally, if political and economic relations between the West and the Russian Federation can evolve toward the level of mutual trust and interdependence that now exists between the NATO countries and Japan, it will be possible to bring the Russian Federation fully within the Coordinating Committee for Multilateral Export Controls (COCOM) framework. (Russia is already a participant in the COCOM Cooperation Forum.) When that point is reached, the major efforts of export administration can be focused exclusively on the problem of non-proliferation and re-export to third countries.

At the same time, the need for controls on the exports of both the United States and the Russian Federation to third countries "of proliferation concern" is likely to increase. If defense conversion in the Russian Federation does not proceed expeditiously and comprehensively, the financial pressure on Russian defense industry to export technology and weapons to whomever will buy them will continue to grow and thus undercut efforts to limit destabilizing transfers of arms and dual-use technologies. This development will make it much more difficult to agree upon or harmonize export administration measures on dual-use technology for the purpose of controlling proliferation. It is urgent, therefore, that the United States and the Russian Federation agree on an appropriate export administration regime and that the United States support Russia's effort to become less dependent on the export of arms, just as it too must seek to limit its dependence on certain types of foreign arms sales.

Defense Conversion

With the end of the Cold War, the conversion of a significant portion of the defense research and development (R&D) and defense manufacturing capability of both countries to entirely civilian (i.e., commercial) use is now a necessity.[3] It is more urgent,

[3] One good way to address Russian short-term concern with survival is to deal with it under the rubric of defense conversion. Successful conversion will require changes in both the product lines and customer markets of Russian enterprises and institutes. For the latter, Russian technology needs are mainly in the area of production processes, e.g., quality engineering. For the West to help Russia in this aspect of conversion reduces the risk of open diversion in the short term but admittedly makes easier the misuse of dual-use technologies in the long term, thus underscoring the need for confidence building.

however, in the Russian Federation because of the relatively greater collapse of support of defense (and other) research institutions, as well as the need for stronger commercial R&D if Russia is to become competitive on world markets. Moreover, the radically changing nature of military doctrines in both countries requires a restructuring of the mission, scope, and goals of the remaining defense R&D and manufacturing capabilities of both countries.

Brain Drain

The Russian Federation is apparently suffering a loss through emigration, either permanent or temporary, of some of its most talented scientists and engineers. This phenomenon is often referred to as the "brain drain." While the scope of this discussion was not intended to cover the entire range of issues associated with the problem, one aspect *does* strongly impinge upon the consideration of sensitive dual technology—namely, the brain drain of scientists and engineers possessing expert knowledge on the design, testing, and construction of SDAs who move to countries of proliferation concern. Controlling this highly dangerous type of brain drain, the extent of which is not accurately known, must be a high priority of both countries. It will require a combination of efforts by the Russian government to identify such individuals and provide incentives for them to remain in the country and by the United States government (and other interested governments) to continue to provide additional monetary support for this effort (or to provide these individuals with sufficiently attractive working conditions in the United States and other interested countries to facilitate the control of this emigration process at the international level).

Sustaining Russian Science and Technology

Some—but not all—of the problems associated with technology proliferation and brain drain can be alleviated through foreign and domestic sponsorship of R&D programs in the Russian Federation that productively engage in new areas those who were previously involved in defense R&D. Such foreign support presumably also would encourage greater openness, which would have the additional benefit of increasing confidence that advanced technology was not being used in the secret development of new Russian military systems. Beyond simple sponsorship, the establishment of joint programs involving teams of scientists and engineers from both countries may be even more efficacious. Such activities are highly desirable and should be encouraged. (The design of such activities was not, however, a major focus of this joint NAS-RAS activity.)

It must be understood that, at the present time, it is virtually to think about anything beyond the problem of survival. The impact impossible for Russian institutions, either industrial or academic, of severe budget cuts has been nothing short of devastating, and it is hard to focus on longer term issues, even though they may eventually be critical for Russian science and Russian industry. Therefore, even if issues such as export administration for limiting proliferation may be extremely important to the security of the Russian Federation in the long run—as we believe they are—the short term pressures could precipitate actions and decisions that prejudice long-term solutions. In our collective judgment, this requires that we propose short-term actions.

Fortunately, several of our recommendations address the short-term issues in a manner entirely compatible with long-term goals. These steps are primarily to offset that part of the technology proliferation and brain drain that might damage the national security interests of both countries. They also include steps to support appropriate Russian R&D, either through direct grants or joint research programs, and possibly to hire directly Russian scientists and engineers on a temporary basis so that they might be encouraged to return to Russia after a few years.

In the remainder of this statement, the four central problems identified above are discussed, first from the standpoint of the United States and then from the standpoint of the Russian Federation. These sections are followed by a set of recommendations that have been extensively discussed by the two sides and which they now endorse unanimously.

In order to make it easier to understand the highly complex and interrelated issues presented in the document, it was agreed that the issues would be presented in a uniform way. Thus, both the presentation of the issues as seen from the perspective of each country and the recommendations which follow are organized under three main rubrics: national security, access to technology of proliferation concern, and confidence-building measures.

ISSUES FROM THE PERSPECTIVE OF THE UNITED STATES[4]

Several issues were identified as concerns for the United States (and to most, if not all, of the COCOM countries) regarding the management and control of militarily sensitive dual-use technologies during the transition of the Russian Federation to a stable, democratic society with a normally-functioning market economy. These issues focus both on the residual problem of diversion of dual-use end products and process technology to military applications within the Russian Federation and on the possibility that technology, end products, and/or know-how could be made available to countries of proliferation concern.

[4] This section was written by the members of the NAS delegation, and its inclusion in the Joint Statement does not necessarily imply that the Russian delegation endorses or shares the viewpoints presented below.

National Security

The predominant security concern of the United States and its COCOM allies during the past forty-five years was the threat, both nuclear and conventional, posed by the former Soviet Union and its Warsaw Treaty allies. With the dissolution of the Warsaw Pact and the breakup of the Soviet Union, that threat has now largely dissipated, although concerns remain about the chaotic political and economic evolution of the FSU and its potential for reversal. In addition, the large number of remaining nuclear weapons and missile delivery systems (far more than necessary either to defend adequately the national territory of the Russian Federation or to deter aggression from other potential threats) and the large numbers of conventional weapons, many of which could be substantially upgraded through access to Western technology, are cause for concern. Indeed, the fundamental NATO doctrine of reliance on "technology force multipliers" (i.e., using advanced technology to overcome numerical inequalities) in order to maintain strategic force parity has created an inherent conservatism with regard to the complete elimination of controls on sensitive dual-use technology.

The reluctance of the United States to agree to the elimination of controls is likely to continue until such time as it is apparent that the economic, political, and social upheavals in the Russian Federation will be resolved peacefully, leaving in place an open society that is integrated with the global market economy. Part of this reluctance is also no doubt an inevitable result of the fact that old ways of reflexive thinking and behavior, born out of more than forty years of the Cold War, take time to change (on both sides). It also takes time to build mutual trust and to bring "normality" to political, economic, and social relationships.

At the same time, the revelations about the proliferation of SDAs resulting from the recent war in the Persian Gulf and from the activities of certain other countries, have resulted in a substantial upgrading of this problem, relative to the old challenges of the Cold War era, as a priority national security concern. There are, however, two key differences between the new security threat posed by SDAs and the old Cold War concerns. One is that there is not the same unanimity of view among the NATO countries and the other advanced industrialized nations in the West regarding either the specific dimensions and implications of the threat (e.g., which specific countries ought to be considered the targets) or how to respond to it. The other is that a coherent and effective response can only succeed if it is fully multilateral, meaning that it must include the Russian Federation and preferably the other states of the Newly Independent States (NIS) possessing SDAs, as well as the People's Republic of China and other potential proliferating countries. These circumstances make the new security threat far more complex and difficult to respond to.

The end of the Cold War, domestic economic and budgetary pressures in the United States, and changes in the global economy (i.e., the U.S. no longer has a monopoly in many technological and industrial sectors) have set in motion other fundamental changes in the United States that also affect national security. The process of consolidation and reduction of the U.S. defense industry is already well underway, causing painful economic adjustments and labor displacement, and serious consideration is being given to a major reorganization and reduction of the federal laboratory system. In this respect, the United States and the Russian Federation share a common problem. They also share in common the fact that they both confront increasing pressure to accelerate economic growth, in part by relaxing restrictions on sensitive dual-use exports.

Access to Technology of Proliferation Concern

During the past twenty years, there has been a significant reversal of the post-World War II model of military development. Since the early 1970s, a growing fraction of the new technology required for the components and subsystems of the next generation of military systems has been derived from or closely related to commercial (i.e., civilian) development efforts, rather than programs strictly and separately supported by the military. Moreover, following the philosophy of "spin on," largely pioneered by the Japanese, companies are actively looking for opportunities to apply commercially-developed technology to military systems, rather than the other way around as had previously been the case. Indeed, it is clear that new commercial technology developments will inevitably find their way into military systems. It is only the rate of such introduction and the degree of openness associated with it that is subject to control.

To maintain excellence in defense technology in the current budget climate, the U.S. Department of Defense must take advantage of the great overlap between key commercial technologies and military critical technologies. It must therefore both exploit the commercial technology base for non-defense unique technologies and focus its development programs on key defense-unique technologies. As a result of this policy, the U.S. approach will be much closer to the coupling of the defense and commercial technology bases.

In Russia, the structure of the technology base is currently quite different from that of the United States, but the end result may be the same. The Russian defense technology and industrial base historically has been clearly dominant, while the commercial base, in many cases an offshoot of the defense base, has not succeeded in producing affordable and quality consumer goods to any significant degree. Russia, however, has stated that it will rely on the conversion of its military enterprises to meet the demand of the consumer market while simultaneously using arms sales as a mechanism to finance this conversion. The country is therefore likely to maintain or even strengthen the close coupling between defense and commercial technology bases.

This tight coupling of the technology bases in both the United States and the Russian Federation, while unavoidable, is exactly the opposite of what we would like to occur as we promote the transfer of dual-use items and technologies to the former Soviet Union. More specifically, end use controls which attempt to isolate a dual-use technology from exploitation by the military will be much less likely to succeed if the defense and commercial bases are either the same or very similar. Verification, for the same reasons, will also be more difficult.

These changes in the process of military technology development, together with the rapidly growing and wide-spread availability (i.e., commoditization) of many previously-controlled items, such as personal computers and certain types of semiconductor chips, make the continued enforcement of comprehensive restrictions on the export of sensitive dual-use technology extremely difficult. These new circumstances suggest that future efforts to control sensitive technology will require that an assessment be made of its actual "controllability," i.e., whether the item in question is widely available and whether access to it actually can be constrained. They also suggest that it will be necessary to identify, through both national means and bilateral consultation, specific "chokepoints" in the process of technology development and deployment—particularly in terms of its military application—that enhance the possibility of control. In addition to identifying effective choke points, it will be necessary to establish separate measures for the practical marking, tracking, and verification of end uses. Such schemes are nowadays more readily adopted and useful in view of the advances in information base, analysis, and communication technologies.

Confidence Building

The United States continues to maintain a number of significant concerns regarding the willingness and actual ability of the Russian Federation, as the largest republic of the former Soviet Union, to control militarily sensitive dual-use technologies. Foremost among these concerns is the prospect for a long-term, stable situation in which a market economy and a politically open democracy can take root and grow. A second critical concern is that the process of conversion of military industries now underway within the Russian Federation may not be irreversible. It is likely that confidence in the permanence of the process can be increased only through a policy of openness, such as making such converted enterprises open to foreign access and involvement. A third major set of concerns relates to the existence of a competent civil authority with the will and capability to enforce the laws, decrees, operating regulations, licensing procedures, and enforcement practices recently adopted by the Government of the Russian Federation. These concerns are deepened particularly by the realization that military research and production centers are under extreme pressure to find foreign financial support to ensure their survival for the near-term future. Given this strong financial incentive to export technology, the vast number of research and production centers and their employees, and the recent general lack of enforceability of Russian laws, the United States undoubtedly will pay close attention to the actions of Russian Federation export administrators. Once again, openness, a process of regular and frequent consultation, and the results of actual experience are the best ways of building trust on these matters between the two nations.

ISSUES FROM THE PERSPECTIVE OF THE RUSSIAN FEDERATION[5]

The problem of dual-use technologies is no less important for Russia than for the U.S. or other leading industrial powers of the contemporary world. At the same time, however, the specifics of the internal political and economic situation in Russia and the countries which surround it are such that this problem has some substantial aspects that are particular to Russia.

First, the Russian Federation has an economy and an armed forces that are completely inconsistent with its national interests. Furthermore, it faces new military threats which force it to revise the list of countries to which it should not sell armaments or sensitive dual-use technologies. A special concern is caused by the unstable regimes to the south of Russia.

Second, the dissolution of the strictly controlled old Soviet borders, seizure of weapons arsenals, transfer of governmental power into the hands of extremists in nearby countries, and the proximity of conflicts to Russian industrial centers and other assets (such as dams and nuclear power stations), has produced a situation in which short-range, high-precision conventional weapons present a graver danger than that posed by the nuclear missiles of former "potential enemies." Consequently, the list of restricted technologies should be expanded to include the technologies related to these advanced conventional weapons.

Third, the establishment of sovereignty in the new states of the former USSR is unfortunately being accompanied by the weakening of legislative, executive, and judicial powers, a rise in crime, and the formation of organized crime syndicates which include civil servants. The problem of non-proliferation is also exacerbated by the unification of organized crime structures on an international level.

Fourth, the majority of scientists and engineers in both Russia and other NIS countries do not have a clear understanding of Western legislative norms for research and the use of research results. Past experience in classified research in the USSR had little in common with international law. Consequently, the breaches of international norms dealing with dual-use technologies may sometimes be unintentional. In order to solve this problem it is necessary to create high-quality and understandable legislative guidelines and then make them available to scientists and engineers. This process may be essential for the conduct of research carried out under contract to U.S. Entities.

[5] This section was written by the members of the RAS delegation, and its inclusion in the Joint Statement does not necessarily imply that the NAS delegation endorses or shares the viewpoints presented below. This section is a shortened version of the full Russian text, which is presented immediately following this statement.

National Security

The dissolution of the Soviet Union with its highly integrated industries, unitary border, and united armed forces has seriously complicated Russian national security concerns. This situation is further complicated by three factors: the current economic crisis; the problems facing the Russian research and development establishment; and a resultant lowering of Russia's sense of national security.

Russia must now find a compromise between prescriptions for economic growth and necessities for economic survival. This process also will be influenced by trade restrictions due to both Western, and primarily American, export administration concerns and the legitimate national security interests of the Russian Federation. Of key importance in this area will be barriers to Western investment that are caused by the non-convertibility of the ruble, absence of contract and property law, differences in business management practices, etc. Also of concern is the need of military industrial complex and related enterprises in the mining and processing industries to obtain income outside of state procurement contracts. This financial pressure creates a strong incentive on these enterprises to sell dangerous technologies both internally to commercial enterprises and externally to foreign customers, and such sales are especially common in "off-shore" and/or "border" trade.

Related to Russia's efforts to stimulate economic growth are concerns about imports of sensitive Western technologies. As previously mentioned in the joint statement, new technologies do find their way into military applications for reasons of national security. There is therefore an urgent need to establish bilateral agreements on the control of technology transfer, the application of such technologies, and the commodities produced with the application of these technologies so that the importing of sensitive Western technologies will not eventually conflict with Western security interests. In particular, these agreements are needed so that Western technologies are not uncontrollably transferred into the Russian military and/or are subject to re-export. Similarly, these agreements are also needed so that technologies which result from Russian defense conversion and are exported to third countries are not independently diverted to military applications or re-exported from those countries.

As previously mentioned in the joint statement, there is currently a massive disinvestment in Russian science. This disinvestment has resulted not only in heavy losses being taken in world renowned Russian scientific schools, but also in financial pressure on military scientific establishments that provide countries of proliferation concern with the means of strengthening their scientific establishment. The loss of government funding of science in Russia has led to a precipitous cut in employment in the Russian Academy of Sciences and in industrial research institutions. In addition, the research conditions for the remaining scientists are very poor. As a result, there is an internal "brain drain" of specialists to Russian commercial entities and an uncontrolled (and probably uncontrollable) external "brain drain" (i.e., emigration) of specialists to foreign countries. In the future, the emigration process will likely predominate. All of these processes are being exacerbated by the increasingly complete isolation of Russian scientific communities, which is produced by the termination of the delivery of foreign scientific literature and the sharp reduction in Russian participation in scientific exchange possibilities, international scientific events, and even intrastate scientific exchanges.

All of the factors described above have produced a situation in which Russia's confidence in its national security is growing dangerously weak. Considering the historical experience of this century and the legacy of Soviet authoritarianism, these factors may in turn lead to the militarization of Russia. Furthermore, since Russia now controls a substantial number of the dangerous technologies and strategic armaments of the former USSR, the dissolution of the country would unavoidably lead to the completely uncontrollable proliferation of these extremely dangerous technologies and armaments.

Access to Technology of Proliferation Concern

While the Soviet military virtually never received any "spin-on" technologies from the civilian sector of the economy, new technologies were "spun-off" to civilian industries from military enterprises and a certain percentage of military production was dedicated to civilian goods as stipulated by state order. The RAS delegation therefore believes that it is more important for Russia to look for military technologies that can be spun-off to the civilian sector than to identify civilian technologies to be spun-on to the military sector. This process, as discussed above, may raise several concerns about the proliferation of sensitive dual-use technologies, and the successful and safe transfer of these technologies is largely dependent on two issues: defense conversion and the efficacy of Russian export administration structures.

The conversion of Russian defense industries may have both positive and negative impacts on Russia's economy and national security and the building of trust between Russia and Western partners. When the conversion process is financially and materially supported, it is feasible to restructure the enterprises to produce for new markets while also reserving some minimal capacities for the quick reconversion of some facilities to meet the contingency of a crisis. Successful defense conversion leads to the general rise of a healthy economy, an indirect strengthening of Russian national security, and a direct rise in trust between Russia and other countries.

An unmanaged crash conversion produces exactly the opposite effect. This would result from the state's decision to stop completely the procurement of armaments and to issue directives to defense enterprises for the production of civilian goods (which, as currently produced, are usually worthless). In this case, an excess of armaments would be produced but not purchased by the government, and strategic raw materials, technologies, and know-how would begin to proliferate uncontrollably.

Related to the issues of export administration and defense conversion are Western concerns over reconversion and the foreign funding of Russian defense enterprises and institutes. The concern of the United States and other Western countries related to the reconversion of Russian enterprises seems to the RAS delegation to be unfounded and, to some extent, unilateral. A state of internal instability should not obviate Russia's right to national security and defense against foreign threats and aggression. Under such contingencies, dual-use technologies (including imports) would be used in the interests of the country's defense. In order to alleviate the concern which this fact may raise in the United States, Russia and the United States will probably have to exchange information (on a mutual basis) related to the current places of possible reconversion down to the level of the enterprises identified for reconversion and the specific technologies to be used. We hope that this will lead to some level of enduring trust between the two countries.

Also, as previously mentioned, there is a new proliferation concern rising from the uncontrolled foreign financing of both private and state enterprises. Regarding the uncontrolled application of dual-use technologies, a special concern is caused by the increasing penetration of investment capital from countries to the south of Russia for the financing of Russian firms, including defense enterprises.

Concerning the efficacy of Russian export administration bodies, it is important to note that the creation of the Russian Federation's state structures has been more complicated than the creation of other NIS countries' state structures. This is due to the historical fact that while other republics of the USSR had their own government agencies under Soviet rule, Russia was the site for only all-union bodies which blocked both Russian sovereignty and the creation of Russian national institutions. Thus the formation of new Russian state agencies really began after August 1991, and the formation of export administration bodies started only in the summer of 1992.

Formally, export administration bodies exist in all relevant ministries and institutions of the Russian Federation, and the primary legislative basis for export administration and the activities of its related institutional agencies have been passed. (Note: the Presidential decree on Dual-Use Technologies was passed a few days after the end of the NAS-RAS meeting in December, 1992.) Expert scientific support for Russian export administration activities, especially in the field of dual-use technologies, is provided by the RAS council on export control. In addition, a special RAS group on dual-use technologies and related issues, established by the RAS Presidium, is the result of prior Russian-American interacademy meetings.

To accelerate the convergence of Russian export administration policies with international standards in effectiveness and reliability, it is necessary to solve the following problems: 1) creating an adequate legislative and executive basis for the structure as a whole and each of its institutional bodies; 2) overcoming the lack of transparency and openness in the administrative and other non-classified activities of enterprises and scientific institutes; 3) installing an effective licensing system in the

Russian Federation regarding its rights in both the internal and international arenas, including protection for intellectual property rights; 4) overcoming the present ability of Russian enterprises and institutions to conclude contracts with foreign buyers, including contracts for dual-use technologies and armaments, which circumvent national authorities in respect to export authorization, registration, and licensing; 5) instituting customs controls and bringing them up to a sufficient level of effectiveness, particularly at borders with the neighboring states of the former republics of the USSR.

Confidence Building

In defining the approaches to building a reliable and long-term atmosphere of mutual confidence, it is necessary to raise and to stress the issue of *mutuality*. All bilateral talks are being conducted only because the healthy forces of both countries recognize a mutual danger, including the danger to the military strategic potential of Russian Federation, and see a way to diminish this danger through a mutual search for confidence-building measures.

Thus, it is not helpful to restate continuously that Russia, as the inheritor of the USSR, has been defeated in the Cold War. Russia does not consider the political crash of communist ideology in the world and the subsequent economic crisis to be the country's defeat. The sooner this crash is seen as a very hard road to a victory—the victory of common sense, human rights, and united human community—the faster Russia will be able to travel the road to victory together with the rest of the civilized world. The RAS delegation believes that it is important for the Russian Federation to build relationships based on mutual confidence with both the U.S. and Western Europe and to join the various international regimes related to export administration. It also believes that Western countries must be sensitive not to use a double standard against Russia in regard to international weapons and technology sales.

Considering the current economic, political, and military situation in Russia, our country is not in a position to launch any premeditated aggressive moves. Nevertheless, this does not mean either that Russia, under conditions of explosive instability, would be incapable of launching such an attack in the future, or that a threat to Russia cannot exist from other states. Russia must therefore seek allies and work toward relations of complete trust and openness with them. In fact, for many geopolitical, strategic, and historical reasons (originating from the times when the USSR and the U.S. shared the burden of global responsibility), the convergence of Russian interests with other countries, up to and including allied relations with the United States, seems most natural. At the same time, however, Russia must consider the alliance obligations of the United States as well as its own European interests.

The Russian Federation is also interested in the development of political and economic relations with West European countries and in strengthening confidence in all spheres—including strategic cooperation and, particularly, joint efforts on the proliferation of precision guided munitions technology. Therefore, after constructing a broad relationship based on trust with the United States, Russia should focus on cooperation with the EC in the areas mentioned above. There is also a complete convergence of ecological interests of both Russia and these countries, and Russia's readiness to participate in international measures for the detection and suppression of unauthorized missile launches presents another area for cooperation. In addition, Russia may be the most interested of all European countries in the creation of an international system for the prevention and/or containment of local tensions and conflicts in Europe. In the future, Russia also may be interested in expanding these "zones of confidence" in the fields of dual-use technologies, export control, non-proliferation, and verification with a number of Asian-Pacific countries, particularly Australia and New Zealand.

The development of these zones and the realization of confidence-building measures in issues as vital as the proliferation of strategically dangerous technologies and armaments are inconceivable in theory, and impossible in practice, without the equal and comprehensive incorporation of the Russian Federation into the system of existing international treaties, agreements, and conventions in the this field. First and foremost are the following international regimes: 1) Coordinating Committee for Multilateral Export Controls (COCOM); 2) Nuclear Suppliers Group; 3) Convention on Biological Weapons; and 4) Missile Technology Control Regime. (More information on the Russian perspective on joining these regimes is presented immediately following this statement.)

As in the sale of certain missile technologies, a number of leaders of the Russian military-industrial complex believe that international restrictions, particularly on armaments trade, often discriminate against Russia. When Russia leaves an international weapons market for either economic reasons or certain political agreements, her "warm shoes" are immediately filled by other countries (including United States), and very often these sales circumvent these countries' laws and obligations. Such a state of affairs is completely unacceptable to Russia from both an economic and a political point of view. It also constitutes an unhealthy factor that impedes confidence-building.

PROPOSED RECOMMENDATIONS

The NAS-RAS committee became well aware that Russian enterprise and institute directors believe that they must either find foreign sources of income or face, in some cases, the fact that their immediate survival may not be viable. While it is clear that Western, and particularly U.S., companies and institutions are the Russians' first choice for partners, the "excessive cautiousness" which the West has displayed in investing in joint projects in the former Soviet Union (as viewed by many Russians) has resulted in the sale of technology in many fields to countries to Russia's south and east by Russian enterprises. Thus, the dire financial status of Russian military research and production enterprises presents: 1) a pressing need to effectively implement export administration measures in Russia's newly developing market economy; 2) the necessity to have an administrative structure which recognizes the legitimate economic needs and rights of Russia's enterprises; and 3) the need to ensure that Russia's scientists and engineers are successfully and safely converted to civilian pursuits in order to assist economic recovery and to prevent sensitive technology proliferation.

In response to these problems, the NAS and RAS delegations have formulated the following proposals.

Access to Technology of Proliferation Concern

1. It is clear that the Russian Federation and the United States will have to work together closely if they hope to control access to key technology related to SDAs. Since both the Russian Federation and the United States developed most of this technology and its applications to SDA weapons systems, the two countries should take the lead in managing access to technology of proliferation concern in consultation with their allies.
2. The NAS-RAS committee believes that it is of foremost importance to implement an effective and fair system of export administration in the Russian Federation and to complete the reexamination of U.S. and Western export administration policies in the wake of recent revelations concerning the capabilities of certain states to develop SDAs. In the Russian Federation, the government must strive to complete the establishment of an export administration legal authority, effective licensing mechanisms, and enforcement capabilities.
3. The United States can take a number of steps beyond its current advising of the Russian Federation on the means to make its governmental export administration bodies, which already exist, more effective in their operation:

   - The United States, along with other Western countries, should work with Russian authorities to attain a convergence of their export administration lists.
   - Russian specialists, in cooperation with scientists and engineers from the United States, should undertake an effort to identify "chokepoints" for the unwanted export and/or internal transfer of technology.
   - The two countries should consider establishing a bilateral laboratory group that would work to identify and agree upon dangerous dual-use technologies. The researchers for this group could be drawn from the U.S.

national laboratories and defense industries and Russian institutes involved in military research and production.[6]

- The presence of American researchers (along with new Russian export laws and possible technical means of verifying technology use) could generally provide assurance that the U.S.-controlled technology exported to Russia was not being diverted to military applications or re-exported. The United States and Russia thus should also implement international joint programs, sited in Russia, which would involve utilizing controlled technology for selected basic research purposes. One example of such a program would be the export of a supercomputer to the Russian Federation from the United States for a joint program in astronomical research. Given the sensitivity of this technology, however, the Russian Federation will need to fully implement existing export administration laws, and demonstrate its ability to enforce those laws, before the U.S. government will permit the export of a supercomputer.

4. One of the important technology access issues facing the United States and Russia is the ability of the countries to verify the use of exported/imported controlled technology and the status of defense conversion at enterprises that have requested and/or received sensitive technology imports. This issue is particularly important in regard to sensitive U.S. technology exports to Russia which are needed for economic and scientific reasons but pose national security risks due to their possible military applications. Since both countries will need to maintain an ability to reconvert some enterprises to military production during times of impending hostility, it would be useful for the two governments to inform each other as to which enterprises have been identified for reconversion in emergency situations.
5. Another step that can be taken to help verify the use of technology in selected cases is the introduction of technical means of verification as previously mentioned. Concerning high performance computers or powerful networks of workstations or PCs exported to the Russian Federation, the United States could, for example, incorporate a software package into the operating system which would record all users that log on to the computer. This information could then be transmitted via satellite to the United States, or to some other location, as a partial means of unobtrusively verifying the end use of the computer. The information in all cases would be considered confidential, and the United States would provide support for the verification software and ensure that this software did not unduly interfere with the computer's operating system.

[6] The ability of Russian and American specialists to work together successfully on the sensitive issue of dual-use technologies is suggested by this joint statement of the U.S. National Academy of Sciences and Russian Academy of Sciences. There are many Russian institutes, including the Elorma Corporation and the Institute of Chemical Physics, both affiliated with the Russian Academy of Sciences, that are willing to work with American counterparts on this and other topics

6. Both the Russian Federation and United States should employ, as appropriate, new verification technologies (e.g., bar-coding and laser scanning) to verify compliance. It is possible that some of these technologies may be useful in addressing the problems associated with unauthorized reverse engineering or clandestine manufacture.
7. The Russian Federation and United States should also consider strengthening the role of the Coordinating Committee for Multilateral Export Controls (COCOM) and other multilateral agencies (e.g., the IAEA)

National Security Concerns

1. The committee also forwards several proposals in regard to the sale of sensitive technologies and the emigration of Russian specialists who have knowledge of strategically dangerous armaments:

   - It would be desirable for the Russian government to establish its own programs to identify and support these scientists and engineers. Such programs might be modeled, for example, on the Mexican National System of Researchers or similar Japanese programs which provide supplementary support to outstanding scientists and engineers.
   - The Russian and United States governments and scientific and technical communities should seek to ensure that the various centers and programs which support Russian scientists are fully and effectively utilized to help prevent the sale of sensitive technology and brain drain. While one program, the International Science and Technology Center in Moscow, has been implemented specifically to address these issues, scientists and government officials also should recognize and pursue the support provided by other programs, such as the new International Science Foundation for the former Soviet Union (established by financier George Soros), the U.S. SABIT (Special American Business Intern Program) and CAST (Cooperation in Applied Science and Technology) programs, funded by the U.S. Agency for International Development and administered respectively by the U.S. Department of Commerce and the National Research Council, and other sources of funding. A joint Russian-American group could be established to exchange information about these various programs and assess their effectiveness.
   - Both the Russian and U.S. governments also should investigate the possibility of establishing cooperative research programs in Russia in selected areas of science in order to stem the brain drain of key military scientists and reduce the sale of sensitive military technologies.

- As a last resort only, the Russian government should delay the emigration of individuals possessing knowledge related to SDA proliferation concerns to select countries and use this time to offer alternative incentives to the scientists to keep them in the country.

2. The joint committee endorses the intelligence cooperation which has recently been initiated by agencies of the United States and the Russian Federation. This process should involve, at a minimum, the sharing of intelligence information about violators of export administration and proliferation regimes as well as perceived threats.

Confidence Building

The NAS-RAS committee agrees that it is important for the Russian Federation and the United States to adopt a variety of confidence-building measures that would demonstrate each country's trust and ability to abide by mutually agreed export administration rules.

1. The Russian Federation and United States should participate in a series of incrementally sensitive research projects regarding controlled dual-use technologies. Such a series of "gateway" joint programs would demonstrate to each country the other's ability to conduct research utilizing increasingly sensitive technologies without technology diversion.
2. After the point is reached when Russian export administration laws are fully implemented and enforced and as initial experience with sensitive cooperation proves reassuring, the two countries may want to consider eventually conducting audits of each other's export administration reporting, in some instances, in place of on-site inspections. Should inconsistencies in the reporting be evident, either country could then demand a return to intrusive, on-site inspections. In this and other cases, the progress achieved by certain East European countries in establishing viable organizational and procedural arrangements for export administration exemplifies the opportunity presented to Russia for obtaining further liberalization, and the ultimate removal, of the COCOM restrictions.
3. The two countries should establish a joint data bank group which would establish joint lists of restricted technologies and enterprises or "projects of concern" to which certain technologies should not be internally transferred or exported. Alternatively, this activity could be referred to a joint working group as described in the "Access to Technology of Proliferation Concern" section above. Development of methodologies for assessing the degree of risk of dual-use technologies and the means of reducing this risk would be the most important task of such a future joint committee.
4. Both the Russian and U.S. governments should seek to ensure the rapid and unrestricted publication of non-classified, pre-competitive research results to promote openness and transparency in research and to avoid "technological surprise." For the

same reason, the two countries should connect all non-classified research facilities to international electronic networks.

5. The Russian Federation and the United States, as well as other advanced countries, should work to promote openness and reporting to each other about technical assistance to, the training of students and post-doctoral candidates from, and joint programs with countries of proliferation concern.
6. Academic contacts between the two countries should be expanded on perception of threat from cultural, political, economic, technological, and military standpoints. The conclusions reached should be forwarded to the respective governments.
7. The two countries should participate in a variety of international fora, both governmental and non-governmental, that address issues related to dual-use technologies and export administration (e.g., UN, CSCE, SIPRI, IISS, etc.)
8. The two countries should complete work on and implement existing and proposed arms control and other military agreements at the earliest possible time.

COMPLETE TEXT OF "ISSUES FROM THE PERSPECTIVE OF THE RUSSIAN FEDERATION"

The problem of dual-use technologies is no less important for Russia than for the U.S. or other leading industrial powers. Russia, however, must cope with unique aspects of the problem as a result of the specific internal and political problems which it and the countries surrounding it face.

In the new, post-confrontational world created by the dissolution of Warsaw Pact and the USSR, the Russian Federation is a new sovereign power and has become the heir of the USSR. Russia is now faced with an economy and armed forces that are completely inconsistent with its own political interests. Different military dangers and threats are forcing Russia to revise the list of countries to which it is impossible to sell armaments and with which it is necessary to restrict the proliferation of dual-use technologies. The unstable regimes in countries to the south of Russia present a special cause for concern.

The crumbling of the strict border control system of the USSR, the theft of weapons stockpiles and their transfer to extremists, and the proximity of conflicts to Russian industrial centers and other assets (the destruction of which would be ecologically catastrophic) have led to a situation in which shorter range conventional weapons, when used with high precision, have become more dangerous to Russia than the intercontinental strategic nuclear missiles of the previous "potential enemies" of the USSR. Consequently, the list of restricted technologies for limiting proliferation should be expanded to include those technologies which can be used for improving the military-tactical properties of conventional weapons.

Although the dissolution of the USSR left Russia with approximately 80% of the capacity of Soviet defense enterprises and about 90% of its engineering-design and scientific potential, the 20% and 10% of the respective remaining potentials that are located in other former republics do include unique production facilities and laboratories. Consequently, certain states of the CIS, including the Russian Federation, will have to coordinate their lists of restricted dual-use technologies.

The establishment of sovereignty in these new states (the former republics of the USSR) is unfortunately being accompanied by the weakening of legislative, executive, and judicial powers, a rise in crime, and the formation of organized crime groups which include civil servants. Under such conditions, the problem of controlling dual-use technologies—the transfer of which may give substantial advantages to the criminal strata—may be complicated by the unification of organized crime structures on an international level. Control and sanctions against countries, companies, or individuals breaking these regulations therefore becomes at some point a struggle with organized syndicates.

The majority of scientists and engineers in Russia and the other CIS countries lack a clear understanding of Western legislative norms for research and the use of research results. Past experience with classified research in the USSR had little in common with international laws. Consequently, the breaches of international norms dealing with dual-use technologies may be unintentional—they may be the result of ignorance and not of ill will. To solve this problem, it is necessary first of all to have high quality and understandable legislative guidelines, and, secondly, to make them available for study and everyday use by scientists and engineers. This development may be especially essential for the conduct of research contracts carried out under U.S. grants.

These particular aspects of the situation in Russia put into context the RAS delegation's statement of the problems connected with dual-use technologies.

National Security

The dissolution of the Soviet Union with its highly integrated industries, common border (with no border controls between republics), and unified strategic defense system has seriously complicated national security issues for the Russian Federation.

Military-technical and techno-economic problems, which have a direct bearing on the national security of Russia, also have appeared in addition to these military-political and administrative-territorial issues.

1. There is a need to find a compromise between economic survival and the requirements of economic growth. With the increasing globalization of economic relations, this process is clearly influenced by both the requirements and the restrictions imposed due to Western, and primarily American, export administration concerns and the legitimate national security interests of the Russian Federation. These contradictions are focused primarily, but not exclusively, on the following issues:

   - The crisis in the Russian economy and barriers to Western, including American, investment that are caused by the non-convertibility of the ruble, differences in business management, etc.
   - The enterprises of the military industrial complex and related enterprises in the mining and processing industries now must obtain income sources independent of state procurement and budget financing. This process creates a strong incentive for the sale of dangerous technologies (both internally to commercial enterprises and externally to foreign customers) and is especially common in poorly controlled off-shore and/or border trade.
   - New technologies, including those already transferred to industry and those still being perfected in research organizations, find their way into

military applications for reasons of national security. To ensure that the transfer of these technologies does not conflict with international trade interests, there is an urgent need to establish a system of bilateral agreements on the control of technology transfer, the application of such technologies, and the commodities produced as a result of their use. The establishment of these agreements is particularly needed so that technologies imported from the West are not uncontrollably transferred into the Russian military industrial complex and, more importantly, are not re-exported. Similarly, these agreements are also needed so that technologies which result from Russian defense conversion are not diverted to military applications and/or re-exported to third countries.

2. The impact of the economic crisis has become extremely severe for Russian science, threatening heavy losses for world-renowned Russian scientific schools and an overall degradation of Russian science. The crisis also presents the possibility of an uncontrolled increase in military-related research in countries of proliferation concern. This statement may be expanded as follows:

- Cutbacks in government financial support for basic research and for military-applied science have brought about a precipitous cut in employment in both the Russian Academy of Sciences and industrial research institutions. In addition, working conditions for the remaining scientists have badly deteriorated due to a lack of funds for equipment, reagents and salaries.
- The conditions described above have produced a "brain drain" from Russia, encompassing both scientists who have lost their jobs and those who have left their positions due to dissatisfaction with poor research conditions. We have seen not only a departure of specialists to commercial enterprises, but also uncontrolled emigration to foreign countries. Lately, the emigration process has become predominant.
- All these processes are complicated by the sharp reduction in opportunities for scientific exchanges, participation in international scientific events, and even mutual scientific exchanges within Russia. This process leads to segregation and the formation of closed scientific communities isolated from the mainstream of international scientific developments. The isolation of Russian science is becoming virtually complete due to the high cost of communications, the termination of the delivery of foreign scientific literature, and the reduced publication volume of domestic scientific journals.

3. Viewed in their entirety, the factors described above may give rise to a sense that the state is experiencing an inescapable reduction in national security guarantees below a critical level. Considering the country's historical experience and the continuation of

some consequences of the authoritarian regime, these factors may in turn stimulate antidemocratic processes and ultimately promote the militarization of Russia. The international community should also consider the fact that since Russia has largely managed to absorb the dangerous technologies and strategic armaments of the former USSR, its collapse, which is quite possible given its perception of insufficient national security, would unavoidably lead to the completely uncontrollable proliferation of these extremely dangerous technologies and armaments.

Access to Technology of Proliferation Concern

Defense research and industries virtually never received any "spin-on" technologies from the civilian sector of the economy in the former USSR, and it should be noted that Russia has inherited the more or less destroyed Soviet economic structures, which operated neither efficiently nor productively and constantly experienced shortages of resources. New technologies were, however, "spun-off" to civilian industries from the military, and the state's central planning bodies did stipulate that a certain percentage of military production had to be dedicated to civilian goods. Thus, considering the Russian spin-off philosophy and the lack of sufficient economic incentive, it is senseless to speak about new technologies making their way into military industries. Regarding technologies indigenously created in the former USSR and in contemporary Russia, it is much more important to look for ways in which new technologies can be transferred into civilian (commercial) industries. There may be some concern, however, regarding dual-use technologies imported from the West. The following issues are critical in resolving this problem while meeting international obligations and allaying foreign partners' concerns.

1. While the conversion of defense industries has an unquestionably positive impact on the civilian sector, it can also have a negative effect on the economy, national security, and confidence-building measures between Russia and Western partners due to the proliferation of high technology to strategically dangerous Third World countries. In cases where conversion is financially and materially supported, it is possible to restructure enterprises for the manufacture of new products and spare parts while maintaining some minimal capacities for rapid reconversion in the event of a crisis. These developments, along with the incorporation of Russia into the world economy, lead to general economic improvement, an indirect strengthening of Russian national security, and a direct increase in trust between Russia and other countries. Exactly the opposite effect would result from an unmanaged crash conversion in which the state would simply halt its procurement of armaments and issue directives for the production of civilian goods which are largely useless. In this case, an excess of armaments produced but not purchased by the government, as well as strategic raw materials, technologies and "know-how," would begin to proliferate uncontrollably. This would threaten stability in the country itself, in its immediate vicinity, and on a global scale (considering the strategic potential of Russia's military). This situation gives rise to the following questions:

- The concerns of the U.S. and other Western countries regarding the reconversion of Russian industrial enterprises seem to the RAS delegation to be unfounded and, to some extent, unilateral. From a national security standpoint, any country can see the need to maintain its capacity for rapid partial reconversion and slower reconversion of a substantial portion of its industrial base in the event that the international political situation shifts from a danger of war to an imminent threat of war or outright direct aggression. This right is also justifiable for Russia. A state of internal instability should not obviate Russia's right to national security and defense against real external threats and aggression when all dual-use technologies, including those imported, would be used in the interests of the country's defense. Another side of this issue is that, given a certain degree of mutual trust, Russia and the U.S. can, and evidently will have to, exchange information on their current plans for possible reconversion, including details down to the level of specific enterprises and technologies.
- Russian economic reality, as created by the problems inherited from the Soviet Union and the existing crisis, precludes any hope that new dual-use technologies will be developed in the civilian sphere in the near future, with the exception of imported technologies which may have certain military usefulness. Separation of research into defense and civilian spheres occurs during the formulation of the initial outline and technical requirements of R & D. The practice of industrially developed countries regarding the "spin-on" of civilian technology to defense industries when economically advantageous may become economically feasible and consequently desirable for Russia in the longer term.
- In connection to the recent transition to a market economy, there is new concern regarding the possibility of uncontrolled or poorly controlled proliferation of dual-use technologies. The problem stems from the lack of control over new financing sources now being used by both private and, in many cases, state enterprises. In relation to the uncontrolled application of dual-use technologies, special concerns are arising from the increasing penetration of investment capital from countries to the south of Russia for the financing of Russian enterprises, including defense companies.

2. The transition from the disintegrating structures of the former USSR to new Russian state structures has been occurring in circumstances which are much more historically complicated than those in the other republics of the former USSR. This situation exists because the basic principles of Gorbachev's policies, and the Union structures which supported them, involved blocking the development of Russian sovereignty and thwarting the formation of Russian state structures to the greatest extent possible. Thus the formation of these Russian institutions really began only after August 1991, and the creation of an export administration started only in the summer of 1992.

Export administration offices have been established, at least formally, in all relevant ministries and institutions of the Russian Federation, and the primary legislation on export administration and the activities of its related institutional bodies has been passed. [Note: a few days after termination of the NAS-RAS meeting the Presidential Decree on dual-use technologies was passed.] Expert scientific support for Russian export administration activities, especially in the field of dual-use technologies, is provided by the RAS council on export control, augmented as a result of the previous Russian-American interacademy meetings by a special RAS Presidium group on dual-use technologies and related issues. To accelerate the convergence of Russian export administration policies with international standards in effectiveness and reliability, it is necessary to address the following issues:

- Creating an adequate legislative and executive basis for the export administration structure as a whole and for each of its institutional bodies.
- Overcoming the historically-rooted absence of transparency and openness in the administrative-financial and other non-classified activities of industrial enterprises and scientific institutions, with the exception of a certain range of questions involving state and/or military secrets.
- Affirming the domestic and international rights of an administrative licensing system in the Russian Federation with the authority to monitor observance of intellectual property rights.
- Eliminating the ability of Russian enterprises and institutions to conclude contracts with foreign buyers, including contracts for dual-use technologies and military hardware, which circumvent national authorities with regard to export authorization, registration, and licensing.
- Instituting customs controls and bringing them up to the necessary level of effectiveness, particularly with respect to the borders with the former Soviet republics and former Warsaw Pact nations, in order to eliminate opportunities for the re-export of dual-use technologies and armaments.

Confidence Building

In defining approaches to building a reliable and long-term atmosphere of mutual confidence, it is necessary to raise and stress the issue of mutuality. While one may continuously announce that the USSR and Russia as its heir have suffered defeat in the Cold War, these very announcements would represent nothing but the continuation of the cold war. In addition, as the well-known literary hero Khodzha Nasreddin used to say: "You may repeat the word 'halva' as many times as you like, but you won't taste any sweetness." All bilateral talks between the United States and Russia are being conducted only because the healthy forces of both countries still recognize a mutual danger and see a mutual search for confidence-building measures as one of the most radical ways of reducing this danger. Russia does not view the political fall of militant communist ideology in the world and subsequent economic crisis as a defeat for the country, but rather as a hard road to a victory of common sense, human rights, and unity with the world community on the basis of peace and equality. It is from this standpoint that the Russian Federation has identified the following key issues which must be addressed in order to build trust:

1. Considering the current economic and military-political situation in Russia, any serious politician could hardly anticipate premeditated aggressive moves from our country. Nevertheless, this does not mean either that under conditions of protracted instability Russia would be incapable of becoming a source of an unpremeditated threat, or, on the other hand, that there cannot be a threat to Russia from other states. Overall, the situation compels Russia to seek allies and to work for relations of complete trust and openness with them. For many geopolitical, military-strategic, and historical reasons (originating from the times when the USSR and the United States shared the burden of global responsibility), the convergence of interests with the United States, up to and including the establishment of an alliance, may be most natural. At the same time, Russia must consider the alliance obligations of the United States and its own European interests at a time when a number of states—both former republics of the USSR and former Warsaw Pact members—plan their defense doctrines based on potential confrontation with Russia. The Russian Federation thus has an obvious interest in developing political and economic relations with West European countries and building trust in all spheres, including military-strategic cooperation. This interest is particularly valid in light of the common danger of the proliferation of precision guided weapons technology.

Thus, having achieved sufficient bilateral convergence and confidence-building between Russia and the U.S. over a broad spectrum of problems, the next focus for further Russian expansion of the mutual confidence zone should be the countries of the European Community. Cooperation with the EC can occur in the fields of politics, economics, and, with regard to NATO member countries, in the military-political field. Such an approach is well-founded and in agreement with NATO's stated new priorities for the near future. Here, for example, one observes a complete convergence of bilateral interests regarding ecological problems. Russia has already declared its readiness to participate in international efforts to build a unified anti-missile defense system for the monitoring and destruction of intentionally and/or accidentally launched missile weapons. In addition, Russia may also be even more interested than many other European countries in the creation of an international system for the prevention and/or containment and liquidation of local tensions and armed conflicts in Europe.

In the future, one cannot rule out the interest of the Russian Federation in a further expansion of confidence zones relating to policy coordination in the fields of dual-use technologies, export control, and strategic weapons non-proliferation and verification with a number of countries in the Asia-Pacific region, particularly Australia and New Zealand.

2. The development of these zones and the realization of confidence-building measures in such vital matters as the proliferation of strategically dangerous technologies and armaments are inconceivable in theory and impossible in practice without the equal and comprehensive incorporation of the Russian Federation into the system of existing international treaties, agreements, and conventions in this field. First and foremost are the following international regimes:

COORDINATING COMMITTEE FOR MULTILATERAL EXPORT CONTROLS (COCOM)

It is necessary to consider the changed international situation which places the need for a transformation of COCOM on the agenda. The participation of Russia and certain other countries (the former republics of the USSR and former members of the Warsaw Pact), along with the need for a partial change in the perception of regions and countries presenting a danger with regard to the proliferation of dual-use technologies and strategic weapons, necessitates the transformation of COCOM or even the redrafting of the COCOM agreement on the basis of its existing principles.

NUCLEAR SUPPLIERS GROUP

Here the dissolution of the USSR, a former participant in this group, has turned both the international community and Russia itself into hostages of the ambitions of the leaders of the former USSR republics. These republics were the sites of enterprises of the former Goskomatom, Minsredmash and a number of other agencies responsible for mining, enrichment and processing of raw materials, for applications of fissionable materials for both civilian (nuclear power, medicine, etc.) and military purposes. Unfortunately, the number of these countries exceeds the number of former republics where nuclear weapons of the former USSR were deployed. These weapons are to some extent controlled even now by the staff of the joint armed forces of the CIS and by special units subordinated to the Russian Federation. In general, the enterprises that use nuclear technologies predominantly at the level of raw material processing and enrichment are currently unable to operate efficiently without support from Russia's industrial structures. Nevertheless, there is still a serious danger of proliferation of technologies and processed materials and migration of nuclear specialists. Under such conditions it is necessary first of all to transfer to the Russian Federation the comprehensive and full scale international rights previously held by the USSR and, secondly, to encourage the fuller participation of Russia in the activities of this group, with effective assistance from the other group members.

THE AUSTRALIA GROUP

Agreements signed under the group's auspices will soon be supplemented by a Convention on Chemical Weapons. Russia possesses a significant pool of chemical scientists, including military personnel, engineers, and skilled technicians and workers with experience in chemical weapons. With adequate investment in applied research and production under the guidelines set by the International Convention, Russia could make a substantial contribution to the elimination of chemical weapons, working openly in cooperation with other nations.

CONVENTION ON BIOLOGICAL WEAPONS

MISSILE TECHNOLOGY CONTROL REGIME

Confidence-building measures in this field have unfortunately been frustrated by industrial and economic barriers. Russian missile manufacturers justifiably believe that the limitations required under this regime on the initiative of the United States are to a considerable extent based on protectionist considerations. As Russia is opposed to the permanent destruction of its missile and space industry, which would substantially worsen the country's already disastrous economic situation, the establishment of trust in this field largely depends on the international community, and primarily on the United States. It depends not on restricting Russian high technologies, but on making them internationally available for peaceful purposes, a process in which Russia is fully prepared to engage.

Furthermore, the best way of achieving mutual trust is joint action. We are currently faced with a challenge which threatens world stability in the twenty-first century—the augmentation of arsenals of weapons of mass destruction by a fourth destabilizing component, i.e., long-range precision guided weapons of secondary ecological destruction. Developing means of controlling these weapons, ensuring their non-proliferation, and preventing or reducing the effectiveness of their use would be an ideal field of joint activity for all responsible states in the world. As a result of such joint work, we might achieve a previously unattainable level of mutual trust among nations.

3. As in the case of missile technologies, a number of leaders of the Russian military-industrial complex express the opinion that international restrictions, particularly those pertaining to the arms trade, often discriminate against Russia. If Russia leaves the international weapons market for economic reasons or in accordance with political agreements, its place will immediately be taken by arms merchants from other countries, including the United States., and often in contravention of the laws of these countries. In the absence of adequate economic compensation, such a situation is economically and politically unacceptable for Russia and constitutes an unhealthy factor hindering the establishment of trust.

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HIGH-PERFORMANCE COMPUTING: CONTROLLABILITY AND COOPERATION

Seymour E. Goodman
Department of Management Information Systems, University of Arizona
Vladimir K. Levin
Council Chairman, Russian Transputer Association, RAS Corresponding Member
Ivan D. Sofronov
Head of Computational Mathematics, Arzamas 16, RAS Member
Peter Wolcott
Department of Management Information Systems, University of Arizona
Aleksey V. Zabrodin
Moscow State University

INTRODUCTION

With the end of the Cold War, the relationship between the United States and the Russian Federation has become less adversarial on many fronts, from foreign policy to commerce to science and technology. The hope is that the two countries' basic principles and goals about the nature of relationships between nations have drawn closer. In this context, some of the key features of the Cold War, such as the regimes governing the export of sophisticated dual-use technology from West to East and from North to South, should be reviewed and possibly modified.

At the heart of the issue are questions of which technologies or uses should be controlled and which technologies can practically be controlled in terms of their manufacture or proliferation. Controllability depends strongly on the nature of the technology, its availability on global markets, and the organizational arrangements governing its use and distribution. The control of high performance computing (HPC) is particularly problematic because controllability characteristics of constituent technologies (software, microcircuits, networks, integrated systems, etc.) vary widely, and due to the extraordinarily rapid rate of technological advance and diffusion throughout the world, leading-edge technologies move into the mainstream only a few years after their introduction.

In the past, control efforts have consisted of measures taken by the United States and its allies in the Coordinating Committee for Multilateral Export Controls (COCOM) which assumed active attempts by agencies of the Soviet Union to divert sophisticated technology. Reliance on Soviet cooperation was minimal. In recent years, remarkable progress has been made diplomatically in recasting the relationship between the United States and the Newly Independent States from one that had been fundamentally confrontational to one that is more mutually beneficial. The cooperation of Russians can be a powerful factor in the export control equation. If the Russians can demonstrate their ability and willingness to work with Western governments, vendors, and users in keeping sophisticated technologies from being diverted to military uses or restricted destination countries, it is possible that the iron-clad controls of the past can be eased to the benefit of commerce, scientific progress, and Russian transition to a viable market economy.

In any relationship, including that between countries, the reduction of confrontation does not lead immediately to an establishment of trust. The latter can be accomplished only through the multilateral establishment of procedures and mechanisms to achieve the goals of non-diversion and non-proliferation and through a series of small and incremental steps taken over time in which both parties demonstrate trust, trustworthiness, and a willingness to work together in mutually beneficial ways. These tasks will necessarily involve an element of risk, since measures which give one party complete control over the actions of the other (e.g. iron-clad control over high-performance computer installations) give the latter no opportunity to demonstrate independent good faith and cooperation. Russians must be given the opportunity to demonstrate understanding of and respect for the national security concerns of the United States and cooperate in preventing the diversion and proliferation of sophisticated technology.

In the past, the Soviets' willingness to control diversion and proliferation was questioned, but their ability to do so was not. Strong, centralized political and military institutions effectively regulated sensitive technologies. Today, there are reasons to suspect that the willingness to cooperate has increased. However, it should be noted that the Russians' ability to control has decreased. Partly as a result, concerns about North-South proliferation of technologies to such countries as Iraq and Iran have grown. The Western community should acquire assurance that, under the current conditions of fragmentation and decentralization of lines of authority, the Russians have the ability to establish an effective, civilian, control regime.

This paper examines the present nature and inherent controllability of high-performance computing technologies. It discusses means of control in the context of broader efforts to create an environment in which the need for controls is reduced. Specifically, it sketches a three-track approach that focuses on application domains, institutional arrangements, and technologies and controls in order to building confidence without unduly compromising national security or economic interests.

CONTROLLABILITY OF HIGH-PERFORMANCE COMPUTING SYSTEMS

The High-Performance Computing Act of 1991 defines high-performance computing as "advanced computing, communications, and information technologies, including scientific workstations, supercomputer systems (including vector supercomputers and large scale parallel systems), high-capacity and high-speed networks, special-purpose and experimental systems, and applications and systems software." The ability to store and manipulate large volumes of data and make the results accessible to local and remote users has made such systems powerful enabling factors in a wide variety of civilian and military applications. HPC systems have contributed to leading-edge developments in such diverse applications as weapons design, integrated-circuit simulation, weather analysis, automobile crash simulation, seismic prospecting, and drug design. Computational research has become a third pillar of scientific advance, together with theoretical and experimental research, and is increasing in importance over time.

In this section we examine some of the trends in high-performance computing development in the United States and Russia. We concentrate on those technologies which could be or are most easily obtained in Russia.

Trends in HPC

Over the last half decade in particular, the high-performance computing sector has been highly dynamic, witnessing remarkable advances in performance throughout all classes of machines, component bases, storage devices, architectures, software and software environments, data transmission technologies, etc. While systems with traditional vector-pipeline architectures continue to evolve steadily, the emergence of a variety of commercial massively parallel machines with performances in some instances rivaling or exceeding those of traditional vector-pipelined supercomputers has signaled an important era of transition in the field in which massively parallel processors (MPP) have a significant role in complex and increasingly heterogeneous computing environments. Building on dramatic advances in microprocessor technology, workstations, servers, and accelerator boards have blossomed into a $15 billion market in recent years. Approximately 500,000 workstations are sold worldwide annually.

HPC TRENDS IN THE UNITED STATES

Some of the high-performance computer systems which have been introduced in just the last two years by U.S. companies are listed in Table 1.

The rapid evolution of microprocessor technology is one of the main factors fueling the construction of hardware with impressive theoretical performance. Thanks to manufacturing technologies which can place well over one million transistors on a chip and advances in microprocessor architectures, single-chip microprocessors in volume manufacture today offer 50-200 MIPS. They are small enough that thousands can be combined in a reasonably sized, air-cooled cabinet. Individual microprocessors are the engines for powerful, user-friendly engineering workstations. Several microprocessors can be placed on a single printed-circuit board which can be slipped into standard slots in workstations or even personal computers.

Many MPP manufacturers have chosen to use commercial, off-the-shelf microprocessors to save design and development resources. These include the Intel family of parallel systems (based on 286, 386, and i860 microprocessors), Thinking Machines CM-5 (SPARC), and the Parsytec GmbH Parsytec GC (transputers). Other manufactures, including nCUBE, Kendall Square Research, and MasPar, have chosen to use highly integrated, customized processors on the argument that by tailoring the design to include only needed functionality, more processors can fit in a given space. Although such processors cost more to design and develop, these companies feel the improved performance and functionality outweigh the drawbacks. In general, the industry has not come to a consensus over whether customized or off-the-shelf ICs are preferable.

During the past decade the performance, functionality, and availability of storage systems, high-speed networks, software engineering environments, graphics workstations and visualization software, etc. have increased tremendously (although not necessarily keeping pace with advances in microprocessor technology). High-speed networks which provide access to HPC configurations and support the transfer of large volumes of data have transformed the way in which individuals in the HPC community conduct their research and collaborate with one another.

HPC TRENDS IN THE SOVIET UNION/RUSSIA

The Soviet Union has conducted research and development of digital computers since the late 1940s. Although not without achievements, the HPC industry has not been able to keep up with the scope and pace of Western development, for a variety of systemic and technological reasons. Two of the most significant hindrances have been the complex and cumbersome political and economic structures needed to support the development of complex technology, and, correspondingly, a technology base unable to support the development and manufacture of machines with world-class performance. In particular, the Soviet/Russian microelectronics industry has been unable to achieve large-scale, reliable production of chips with less than 1.5 micron technology (approximately 30,000 transistors per chip). The manufacture of single-chip microprocessors with the level of integration of even the 386 has not been achieved. Table 2 lists some of the principal Soviet/Russian HPC computers prototyped or put into series production over the last decade.

In part to try to achieve high performance using relatively slow components, Soviet designers concentrated their efforts on parallel systems. Collectively, the Soviet/Russian projects cover a spectrum of architectural approaches nearly as broad as that in the West, although not as deep. Two recent exceptions, initiated after the success of vector-pipeline computers in the late 1970s, are the vector-pipelined MKP and Elektronika-SSBIS.

Besides those listed, many projects carried out chiefly within institutes of the Academy of Sciences or the ministry of higher education focused on homogeneous distributed systems. During the 1980s, hardware prototypes were built using available indigenous technology, but in recent years developers have been calling such systems "transputer-like" and have focused their efforts on software, often using real transputers as a development base. Most of these researchers have become members of a newly-formed Russian Transputer Association. Many of these projects have been oriented towards developing parallel co-processors or accelerators for general-purpose host computers.

In the past, national security policies in both the Soviet Union and the Western countries forced the Soviet high-performance computing industry to develop to a large extent independently. Basic information about development trends in the West was available, but developers were forbidden to use Western components and users were forced to rely almost exclusively on indigenous computers. Some architectural innovations served partially to compensate for the weak component base, and users invested much effort in developing models, algorithms, and systems software which would compensate for computer deficiencies. The Russian party feels that such efforts have been very successful for high-priority applications. Little has been published in the West about Soviet/Russian innovations in models and algorithms in particular.

As a whole, the HPC community in Russia continues to suffer from deficiencies in storage devices, although individual high-priority configurations may be reasonably adequately supplied with moderate-capacity storage systems. Facilities for remote, interactive access to HPC installations are at best extremely limited. Only in the 1990s has electronic mail become generally available in Russia.

In recent years, orders for HPC technology and financing for development have been reduced significantly as a result of the conversion of defense industries to civilian production and the deterioration of the Russian economy in general. At the same time, many Russian policy barriers to international contact and cooperation have been lifted, making it likely that the Russian HPC community will in the future be more integrated into the world HPC community.

Controllability of HPC

High-performance computing systems have become a particularly problematic element of the export control regime. The extraordinarily rapid rate of technological advance means that products move quickly from leading-edge to the mainstream, threatening to make specific features of export control regulations obsolete before they are published. High-performance computing as a whole encompasses a wide variety of technologies from components to networks to large-scale systems to sophisticated software which have very different controllability properties. The field, dominated by

American and Japanese companies, is growing more international (e.g., C-DAC in Pune, India has recently started production of the transputer-based PARAM computer) as the user base expands, production technologies are licensed outside the principal countries, and international networks provide access and rapid communications across national boundaries.

Off-the-shelf ICs are not easily controlled. The microprocessors mentioned in the previous section have been manufactured in volumes of 100,000 or more, are small enough that tens or hundreds can be packed in a suitcase, are sufficiently self-contained that units are replaced rather than repaired, and are widely available outside the COCOM member countries. While not all of them, strictly speaking, can be considered commodities according to the criteria spelled out in a National Research Council report on U.S. export controls, they will be within very few years. [National Research Council, 1991.]

All of the massively parallel and conventional vector-pipeline use some customized components. Customized components are easier to control than off-the-shelf or industry standard ones. They are manufactured in smaller quantities, have limited distribution, and are not easily substitutable. The ease with which one could acquire the hardware necessary to build a given machine varies with the degree to which customized components and subsystems are used. We examine three types of high-performance systems which are among the least controllable from the perspective of denying the capability to construct them. We consider other systems not discussed explicitly to be more difficult to construct than these.

INTEL PARALLEL SYSTEMS

The Intel systems grew out of work on the Cosmic Cube at the California Institute of Technology in the 1980s, a system with a hypercube structure using the off-the-shelf 8086 and 8087 microprocessors as nodes. Intel's Supercomputer Systems Division was formed in 1984 to commercialize large-scale parallel computer systems based on an implementation of standard Intel microprocessors. Between 1985 and 1992, Intel introduced three more generations of machines, based on the 286/287, 386/387, and i860 microprocessors, and currently has an installed base of over 300.

In order to keep manufacturing costs low and leverage the enormous amount of research done in the workstation and personal computer sectors of the computer industry, Intel has sought to use commercial and non-exotic technologies to the greatest extent possible. For example, the iPSC/860, introduced in 1990, is constructed using the i860 commercial microprocessors, commodity CMOS memory components, the 5.25" disks used in most workstations, as well as widely used I/O, networking, operating system, and computer language standards.

An exception to this principle is the direct-connect inter-node communications system based on the proprietary VLSI communications chips which route messages from one node to another. These chips were developed and manufactured by Intel based on designs by researchers at the California Institute of Technology. Of all the hardware used in the iPSC/860, these chips would be the most difficult to acquire.

It is, however, a mistake to assume that simply acquiring and assembling the hardware is sufficient to build a high-performance system. Actual performance depends directly on the efficiency with which system resources are managed and data are moved from one location to another. Intel has invested hundreds of man-years and millions of dollars researching the most appropriate ways of managing system resources, taking advantage of the computing power the hardware offers, decreasing software development time, and providing computational results in a useful form. Without the proprietary Concurrent File System (CFS), System Resource Manager (SRM), the NX/2 operating system, and other important pieces of systems software and firmware, the hardware is all but useless. The effort and know-how required to develop the necessary systems software should not be underestimated.

TRANSPUTER-BASED SYSTEMS

A second type of system worth examining is transputer-based systems. Transputers are microprocessors developed by INMOS Ltd. in England. Two important qualities are the ease with which they can be configured into systems of various sizes, and the clear and stable interface between hardware and software which enables software to run on a single transputer or a network of transputers without change or even re-compilation. Because communications between processes on the same transputer or on different transputers uses identical instructions (with the inter-transputer communications taken care of by the hardware), the precise configuration of the hardware is largely transparent to the software.

The core of the transputer market currently is fault tolerant systems and embedded controllers. Significant numbers are also used in large multiprocessors and accelerator boards which can be plugged into commercial personal computers and workstations. Specialized boards are being marketed for basic computation, video frame-grabbing, graphics, A/D conversion, and more. Some boards even incorporate an i860 processor.

Construction of such boards does not require highly sophisticated, proprietary technology. One leading vendor does board design using commercially available CAD systems, purchases commercially available components, and subcontracts out the PCB manufacturing and system assembly. The technology to manufacture eight-layer boards used here does not have to be state-of-the-art, and is within the capabilities of Russian manufacturers. The assembly is a combination of surface-mount (automated) and through-hole (manual) processes, which is within the capabilities of Russian manufacturers.

Multiple transputers can be placed on one board (up to 32 for a board to be used in a workstation). Boards are placed into racks attached to the workstations via an

Sbus-VME converter card, which also is commercially available. No customization of software is required for such an installation. Standard transputer software (the operating system, compilers, a tool kit, etc.) is supplied by INMOS and the vendor serves solely as a distributor. Systems with several hundred transputers and theoretical peak performances of several hundred Mflops can be configured in a straightforward manner.

Because transputers, communicating via built-in serial links and running widely available systems software, can so easily be configured into multiprocessor configurations it is difficult to prevent configurations such as those mentioned above from being assembled. To disable the hardware, the serial links connecting transputers must be disabled. Since the communications facilities are built into the transputers themselves, this is impractical to do, short of physically isolating individual transputers. In multi-board configuration, it would be possible to manufacture specialized boards in which the communications links on the board could be terminated before they reach the edge connector. This would prevent transputers on different boards from communicating with each other, while permitting a modest amount of parallel processing on each board individually.

For large systems consisting of several hundreds or thousands of nodes, the most difficult challenge is not the construction of the hardware, but the development of the systems and applications software necessary to use it effectively. Network operating systems, debuggers, and performance monitoring systems are crucial, and hard to develop. Much time must be spent porting or developing applications. Not yet widely available, such sophisticated software is still reasonably controllable.

The transputers and their basic systems software are not easily controlled, however. Over one million transputers have been manufactured, and annual world-wide sales are over 250,000. SGS Thomson, the principal transputer distributor, has offices in India and the Pacific Rim countries as well as Western Europe and North America. Nearly two dozen companies are value-added resellers that build complete systems based on the transputer.

RS/6000 CLUSTERS

The RS/6000 workstation clusters recently announced by IBM represent an alternative path to high performance computing based on commercially available technology. IBM has widely advertised the fact that a cluster of RS/6000 workstations supplanted a Cray X-MP supercomputer at Lawrence Livermore National Laboratory (LLNL). The hardware consists of standard workstations equipped with boards manufactured by IBM for Ethernet, Token Ring, or FDDI fiber optic networks, and the associated cabling.

The heart of the cluster is in the software. Currently, the cluster can be organized as a serial-batch, or a parallel system. In the first case, each program runs on only one machine, but programs can be submitted to any available computer in the cluster.

Supporting this mode are the Network Queuing System (NQS) or the DQS system, a public-domain system developed at Florida State University. Supporting the parallel execution of a single program across multiple machines are the Network Linda, Parasoft Express, and PVM (Parallel Virtual Machine) environments. The latter is public domain, developed at Oak Ridge National Laboratory.

The most controllable parts of an RS/6000 cluster are the workstations and the individual network boards which are IBM proprietary. Although not yet commodities, with a worldwide installed based approaching 100,000 the RS/6000 is not easily controlled.

As the technology advances, clusters of computers increasingly will be applied to a single job. Gordon Bell, the well-known former Vice President for R&D at DEC and founder of the Gordon Bell Prize for achievement in parallel computation, states that "Important gains in parallelism have come from software environments that allow networks of computers to be applied to a single job. Thus every laboratory containing fast workstations has or will have its own supercomputer for highly parallel applications. The rapid increase in microprocessor power ensures that the workstation will perform at near super speed for sequential applications. LAN environments can provide significant supercomp for highly parallel applications by 1995." [Bell, 1992]

Controlling the Acquisition of HPC

The number of high-end HPC installations is still quite small. For example, Intel has shipped only 300-400 parallel systems; Convex has over 1100 systems in the field; and Cray Research Inc. has an installed base of just over 300 mainline computers plus nearly 100 Cray YMP-ELs. The small numbers of units, single sources, and considerable effort required to install them are among the factors which make it relatively easy to keep track of where each system is located.

From the discussion above we can see that it is possible to construct high-performance systems with a high percentage of generally available, off-the-shelf hardware which is difficult to control. However, the construction of almost all massively parallel and vector pipeline high-performance computers requires some customized hardware and/or software. These components and the technologies necessary to produce them are the best candidates for control efforts. Software design tools for application-specific integrated circuits are commercially available from over a dozen firms [see Smith, 1992], but the technology to manufacture chips based on the designs is still controllable and should be a high control priority.

In addition, the sophisticated systems software needed to make systems run effectively is still a reasonable control target. In spite of the ease with which software can be copied, it is a very difficult task to port it from one type of hardware platform to another. It is nearly impossible without access to source code. This is particularly true of most parallel systems. Proprietary and closely held, the source code is perhaps the most controllable part of such a machine.

Workstations, with global production rates approaching half a million annually from a dozen or more vendors, are not easy to control; neither will computing clusters based on them be. While leading vendors are cooperating with government policies to limit direct sales of restricted technology effectively, the installed base is so large that controls are "leaky" at best. Large numbers of workstations can be obtained easily in the Far East. U.S.-based workstation manufacturers have set up factories abroad. Particularly notable are Hewlett-Packard and Silicon Graphics, Inc. SGI's Iris Indigo workstation, introduced in the United States in 1991, will soon be manufactured in China; HP built a factory in Shanghai in 1990 to manufacture the Apollo 9000 series 400 workstations.

Workstations constitute perhaps the most rapidly evolving sector of the computer industry. With development cycles under a year in many cases, prices on given models drop rapidly following introduction. Users replace models after only a few years of use, creating a large secondary market which is uncontrollable. Developing countries like India appear to have little problem acquiring workstations.

Currently the principal barriers to workstations in Russia have little to do with export control regimes. First, few organizations can afford to purchase machines costing tens of thousands of dollars each. Second, the support infrastructure is poorly developed. Western workstations will run for months without maintenance, but they do fail, and failures are more difficult diagnose and repair than is the case for PCs. As the technology becomes more available and the economic climate improves, these hindrances will ease.

A FRAMEWORK FOR CONFIDENCE-BUILDING MEASURES

We have examined the controllability of HPC technology to restricted countries. We now consider a three-track framework for confidence-building by which systems could be selectively installed and used in Russia. The three tracks are: application domains, institutional arrangements, and the means for controlling or monitoring HPC technologies. For each track, one can envision an evolution, conditional on continued cooperation and trustworthiness, from safer, more secure positions to those which involve greater risk of diversion. The possibilities discussed below are necessarily riskier than what has been permitted for HPC in the past. The tracks are loosely coupled in the sense that movement from more secure to riskier positions on each track can be made at different rates. This flexibility makes possible a wide range of possible confidence building sequences.

The framework does not assume that cooperation at any one level of society or government or within any particular sector is sufficient for establishing confidence.

Russia today is characterized by the decentralization and fragmentation of lines of authority. This creates both difficulties and opportunities, since governments are not as able to regulate the activities—for good or for ill. of individuals and organizations as they once were. The framework requires the cooperation of all individuals and organizations involved, from individual users to national governments.

The success of confidence-building measures will depend to no small measure on the creation of incentives to cooperate for all parties involved. The main idea behind the sequence of confidence-building steps is that observing the agreements at the previous step will open new opportunities or capabilities for the next step. Inherent in the framework, with its emphasis on a sequence of confidence-building steps, is the notion that appropriate behavior today will be rewarded by increased opportunity or capability tomorrow.

Application Domains

The applicability of high-performance computing applications to military concerns varies considerably. Confidence-building measures should initially focus on applications which have little importance to the military and gradually move towards those which are marginally important. According to the Gartner Group's 1991 report on "High-Performance Computing & Communications," the following are examples of applications with little direct military applicability:

- design of pharmaceuticals through the simulation of proteins and molecules;
- structural biology (the use of simulation and molecular dynamics methods to study the time-dependent behavior of biologically important macro molecules);
- human genome project (computer-assisted comparison of normal and pathological molecular sequences for understanding genomes and the basis for disease);
- computational ocean sciences (the development of a global ocean prediction model);
- astronomy (the processing of the large volumes of data generated by Very Large Array or Very Long Baseline Array radio telescopes);
- quantum chromodynamics (QCD) (simulation of QCD yields insight into the properties of strongly interacting elementary particles);

- computational chemistry (simulation of molecules and chemical reactions are critical to the development of new materials);
- financial applications (In the West, sophisticated econometric models and vast databases consume enormous amounts of computing power. The Russian financial infrastructure is still immature, but will, hopefully, strengthen);
- commercial applications (reservation systems, point-of-sales systems, etc., require fast access to large databases).
- Other application domains having a greater, but indirect, relevance to military capability are crucial to economies in general, and the Russian economy in particular. These include:
- transportation (modeling of fluid and gas dynamics in three dimensions, such as the airflow around vehicles and fluid flows within engines);
- superconductivity (Superconductivity can be a critical factor in future power transmission technologies, and instrumentation. The basic properties of superconducting materials are not well understood);
- efficiency of combustion (studying the interplay between flows of various substances and the quantum chemistry principles governing the reactions between them);
- oil and gas exploitation (utilization of improved seismic analysis techniques and modeling the flow of fluids through geological structures);
- nuclear fusion (understanding the behavior of ionized gasses under high-temperature conditions with very strong magnetic fields);
- prediction of weather, climate, and global change (development and use of models regarding the interaction between atmosphere, ocean and biosphere systems, enabling long-range predictions);
- engineering applications (the structural analysis of products).

Because of the potential military application of these areas, confidence-building measures here in the areas of institutional arrangements and control regimes might proceed more slowly than in the non-military cases listed above. Nevertheless, because of their importance, the greatest efforts to make progress should, perhaps, be concentrated exactly in these areas.

Some application domains have direct and critical implications for both economic and military competitiveness. Efforts should be made to explore confidence-building measures here, but with greater caution than in other application domains:

- material sciences (understanding the atomic nature of materials and the development of new kinds of materials);
- semiconductor design (the modeling of how semiconductors constructed out of faster materials operate);
- vehicle dynamics (the analysis of the aeroelastic behavior of vehicles and their stability and ride characteristics).

Finally, there exist application domains which have great military importance, but marginal economic importance. There is little reason to seek confidence-building measures in, for example,

- vehicle signature (the reduction of acoustic, electromagnetic, and thermal characteristics of vehicles);
- undersea surveillance (tracking undersea vehicles);
- cryptography.

Movement from safer to riskier applications could take place on one machine, as the set of allowable applications grows, or in multiple installations. In the latter case, one installation might be devoted to a safe application, while in subsequent ones riskier applications might be allowed. One of the problems that has in the past plagued this approach, and that of permitting remote access to a machine under physical U.S. control, the difficulty of carefully monitoring and distinguishing between applications as they arerun.

Institutional Arrangements

The technical composition and technological content of an installation influence the degree to which it might be diverted. In general, installations can vary in the scope of use, i.e. the spectrum of applications, the size and composition of the user community, the degree of openness about systems use, and the physical distribution of the hardware. In addition, one can categorize installations according to whether they are managed and used by people from one country or from several. The risk of diversion increases as the scope of use increases, the hardware becomes geographically distributed, and the management of the installation becomes more closed, private, and under the control of just one country. If Russians and non-Russians are working together on the same system, it is less likely that sensitive military applications will be run.

Least subject to diversion would be government-run facilities physically located in the United States or another NATO country, where citizens of other countries would be permitted either on-site or remote access. The risk of reverse engineering could be kept minimal, and the risk of diversion during times of international conflict would be essentially eliminated.

A higher risk might well be suitably controlled at public, centralized, tightly managed, international computing centers sponsored and managed by individual governments or international agencies such as the United Nations for the purpose of providing advanced computing resources for non-military research in specific application domains. Over time, the center could expand the user community, possibly offering time to the international community on a competitive basis. Researchers might submit detailed proposals for systems use; individual projects, selected on the basis of appropriateness to the center's mission, could be run under the supervision of the center's staff. Fundamental to such an arrangement would be the on-going surveillance of system activities by the international community.

International installations could also be created within private joint ventures. Companies such as Boeing, Chevron, and Sun Microsystems which routinely use high-performance computing have established joint ventures in aerospace, oil and gas exploration, and computing. These companies could work together with their Russian partners to ensure non-diversion of imported advanced technologies. To a large extent, the success of the export control regimes in the past has been due to self-policing by Western companies; reputable firms have refused to deal with suspect customers because of the possible legal, financial, and negative publicity consequences of illegal transactions. This principle should be applicable in the case of joint ventures as well. Western partners could be given permission to import high-performance computing technologies for use in the joint venture with the understanding that they will be held responsible for any diversion of the technology.

Centers under the management of a single country could be established at state-owned institutions such as universities and government research facilities and at new or newly privatized corporations. The opportunities for diversion would be less at facilities operating with non-proprietary data and applications, where activity could be monitored by a broader circle of observers. It is not clear a priori, however, whether a government organization is to be preferred over a private firm. On one hand, the Russian government could be enlisted as a partner in preventing diversion. On the other hand, a private firm involved in non-military commercial activities would likely have weaker ties to the military. Questions such as these would likely have to be answered on an organizational basis.

Fundamental to the success of any of these scenarios is the establishment of mutually beneficial collaborative efforts using high-performance computing between Russian and Western researchers. The degree of commitment to the relationship (and, correspondingly, the willingness to avoid actions which threaten it) will be a function of the longevity of the relationship, the promise of future benefit, and the importance of the efforts to individual researchers as well as industrial or scientific sectors and the country as a whole.

Russia has rich and extensive pools of data in many branches of science listed in the previous section. In many cases these have suffered from inadequate computing facilities to process and analyze the data properly. A fruitful area of cooperation would be the application of Western computing technology to these data. Cooperation would be more closely knit and longer-term as researchers work together to conduct studies and experiments which generate new data as well.

It is important to note that collaborative work can begin prior to hardware installation in Russia. Russian researchers could literally bring data tapes to the West for processing. Alternatively, such data could be sent electronically to Western machines monitored by both countries.

Institutional arrangements also include government-level monitoring and control mechanisms. In the past, the Soviet government was able to exert effective control over the use and distribution of sensitive technologies through strong military, Party, and State Security structures. Each of them had strong military components and worked to a large extent, at least in the area of high technology, on behalf of military interests. If Russia is to work together with Western countries to control diversion and proliferation, an effective civilian mechanism must be established which will not only exert control in the cases of individual installations, but also will provide continuity and consistency of control from one installation to another and over time.

No such mechanism currently exists with regard to high performance computing. There is doubt in the West that such a mechanism could perform an effective job under Russia's current economic and political conditions. First, the traditional pillars of Soviet society have partially lost their authority as a result of decentralization measures and the unregulated activities of powerful groups such as organized crime. Second, the dire economic straits are forcing individuals and organizations at all levels of society to skirt regulations merely to survive. The sale of advanced technology for hard currency to unauthorized customers is by no means inconceivable. Third, the Russian government has stated that it intends to maintain significant military capability and the ability to reconvert enterprises to military production if necessary.

Under these circumstances it is difficult to envision a civilian authority which could effectively control the diversion and proliferation of high performance computing technologies, even though in principle structures and procedures like COCOM could be established within Russia as they have been within Hungary. Yet such structures must exist and be effective if Russia is to be a partner with the West in this area in the longer term. It is incumbent upon the Russians to design such structures and to convince the West that they are effective.

Technologies and Measures for Control and Monitoring

Given any combination of application domain and institutional arrangement, a variety of control measures can be implemented to regulate and monitor system activities. "Hard" controls are those which seek to prevent diversion by making it difficult to carry them out. Measures which physically or logically control access to a given computer or otherwise restrict performance are of this nature. "Soft" controls, on the other hand, are designed to detect violations, rather than prevent their occurrence. Confidence building measures involve a series of steps which increasingly reduce hard controls and then soft controls. Soft controls in most cases will have to be in place longer than hard controls to provide objective verification that violations have not occurred.

HARD CONTROLS

Hard controls seek actively to limit what can be accomplished on a computer and by whom. The Supercomputer Safeguards Plan (SSP) [Export Administration Regulations 15 CFR 776.11(f)(4)] places very stringent hard controls on systems with Composite Theoretical Performance (CTP) equal to or exceeding 195 million theoretical operations per second (MTOPS). The measures are designed to prevent unauthorized use through denial of physical access to systems by restricted nationals, strict control over the issuing of passwords, precise selection of which applications can be run and under what conditions, complete lack of connection to networks or remote terminals, etc.

Although these restrictions do and will continue to accomplish the goal of controlling access, and while we are examining alternatives to such restrictions, it is important to keep in mind that access is a necessary, but not sufficient condition for performing useful work. The performance and usefulness of a computer are dependent on many things, only some of which are taken into account in the computation of the CTP. Performance depends not only on the raw processing rate of individual processors, but also on the amount of memory available, the throughput of the interconnect system, the amount and speed of external memory, and the throughput of the I/O system. Unless processors are supplied with data at a high enough rate, they sit idle and accomplish no useful work. Software also plays a critical role. The overhead of the operating system, the efficiency with which it manages systems resources, and the effectiveness of the compiler can have a significant impact on performance. Instances in which the performance of the same program on the same hardware is increased 100% or more, simply through the use of an improved compiler, are not uncommon.

In a real-world setting, human factors such as the ease with which a user can accomplish a desired task play a crucial role in determining a system's usefulness. The amount of time spent programming and debugging and the time needed to analyze and interpret results strongly influence the utility of the machine to the user.

Each of these factors provides a means of regulating the effective performance and usefulness of a system. If a system is installed with insufficient external storage, a non-mature software development environment, a lack of sophisticated applications, or inadequate tools to support the visualization and interpretation of results, or is used in an environment in which the ratio of software development to execution is high, the true performance indicated by the CTP will not be realized.

As confidence is built, given installations can be enhanced by selectively relaxing the constraints just mentioned. Processing elements can be added, more external or main memory can be installed, upgraded software packages can be provided, the number of applications authorized for execution can be increased, etc. At each installation, the prospect of future upgrades provides an incentive to cooperate.

SOFT CONTROLS

Soft controls make it possible to monitor the use of a system without necessarily preventing unauthorized use. The Supercomputer Safeguards Plan requires extensive soft controls to be used in conjunction with the hard controls. These include maintaining in a secure fashion usage logs and inspecting them daily, detecting attempts to gain unauthorized access, recording execution characteristics of each program run, and the monitoring of CPU and I/O usage.

Soft controls also serve as guards against proliferation, since the physical location of a system can be easily determined.

Some sort of soft control should be used until a high level of confidence in adherence to non-diversion agreements has been reached.

RECOMMENDATIONS

The recommendations in this section augment those presented in the "Joint Statement of the Delegations of the RAS and NAS on Dual-Use Technologies and Export Administration" [see pp. 3-32 of this publication] and should be considered Within the context of that document.

High-performance computing technologies are evolving very rapidly, particularly in the workstation arena, where new generations are introduced every 2-3 years and five-year-old equipment is often considered obsolete. Recommendations for the control or decontrol of specific technologies are similarly quickly outdated.

- **Recommendation #1: Significantly reduce controls on technologies of which 100,000 units or more have been sold, unless there are compelling reasons to the contrary**.

Currently, microprocessors such as the i860 and T800 and many workstations fall into this category. While not necessarily commodities in the strict sense, such technologies are so widely available that control measures are at best very "leaky."

From an economic perspective, the greatest benefit to American industry will come through the sale of large-volume products. In the West, the total size of the workstation market is an order of magnitude larger than the supercomputer market; the personal computer market is many times larger than the workstation market. In the world in general and in Russia in particular, it is much easier to sell one hundred $10,000 units than one $1 million unit. With a threshold of 100,000 units, great economic gains can be made without severely compromising national security.

A basic premise of this paper is that Russians should be able to participate with Western countries in regulating the diffusion and use of high-performance computing systems, and that they should be given the opportunity to demonstrate their willingness and ability to do so. One means of accomplishing this is through the use of carefully selected sequences of confidence-building measures. Ideally, such sequences would serve as a testing ground for a variety of Russian, Western, and combined control measures, and serve as a model which could be replicated in the future. An additional benefit would be the placement of technology in Russia which could help stem the drain of computational scientists from Russia. But it is critical that the object of export control review be an entire sequence of steps, rather than an isolated installation.

- **Recommendation #2: Consider plans for the installation of individual pieces of technology within the context of a series of measures, possibly leading up to the approval of otherwise restricted technology, conditional on compliance with prior agreements**.
- **Recommendation #3: Give favorable consideration to a number of test-case sequences of confidence-building measures**.

We offer the following sequence as an example. Russian scientists frequently claim that they have developed methods of solving a variety of computational problems which are better in some sense than those developed in the West. As their contribution, in the interests of mutual cooperation in advanced high-performance computing technologies, the Russian scientists can adapt these methods to Western machines. At the first stage of a joint project, a team of Russians would undergo training at a Western university in software development for a particular Western massively parallel system. At the second stage, the Russian team would implement their algorithms, developing programs to run on the parallel machine. This could be carried out in Russia on workstations with the appropriate software development tools. At the third stage, the Russian team would work on debugging and tuning their algorithms in concert with Western colleagues on the Western machine. At the fourth stage, a small configuration would be installed in Russia under the joint supervision of the Russian and American researchers, and Russian and Western export control administrations. Each subsequent year, as long as non-diversion agreements are not violated, the installation would be upgraded through the addition of more processing elements, memory, external storage, software, etc.

A second example could be oriented towards the creation of a prominent computer center which would provide computer time to individuals conducting civilian research in a variety of application domains. At the first stage, a low-end, general-purpose machine from a leading Western supercomputer manufacturer could be installed at a prominent Russian university or Academy of Sciences computer center under the exclusive control of representatives of Western export control organizations and the computer's manufacturer. At this stage the system could be used to run Western applications, or specially approved Russian applications.

At a second stage, a set of research projects, conducted jointly by collaborating Western and Russian colleagues, would be selected and granted access to the machine. An international commission could be established with the task of guaranteeing its appropriate use. Crucial to the composition of this commission would be the full participation of the principal researchers using the system. Additional members would include a representative of the computer vendor, a representative of a Russian monitoring agency, and a representative from the Western export control establishment. Having both Russian and Western researchers involved would ensure that the commission contained the expertise necessary to understand the applications being run. The arrangement would rely for its success on the personal relationships and interests of the researchers and the personal stake each has in ensuring an enduring, successful collaboration.

At a third stage, the set of users and applications could be selectively widened. The international commission would retain a permanent core, with pairs of Western and Russian researchers participating for the duration of their projects.

At subsequent stages, the center could evolve in a number of different directions: the installation itself could be upgraded; the Russians could be given greater and greater monitoring responsibilities; the requirement that all projects be collaborations between Russian and Western colleagues could be removed; and the center could be made available for a broader circle of users and/or applications, including qualified university students.

This second example assumes that successful use of an installation must be based on participants from the individual researchers up through the national government having a strong interest in guarding the system against inappropriate use. Although the existence of a Russian governmental structure with oversight over export control and the use of imported high-performance technology is not a sufficient condition, it is a necessary one.

- **Recommendation #4: Evaluate a variety of "soft" controls, or means of verification of the end-use of high-performance computer technology as a part of a sequence of confidence-building measures**.

The confidence-building measures will lead to fewer iron-clad controls over the use of particular systems, but means of verification of use should be kept in place until sufficiently high levels of trust have been established, or technological developments make them unnecessary or impractical. Computer systems can store detailed logs about certain aspects of computer usage, such as which programs are being used by whom for how long, patterns of system resource usage by individual programs, etc. Although such information is not sufficient to identify the higher-level problem being solved by a particular program, it is very useful in giving a general idea of how a system is being used. Initially, such information would be gathered on location by Western systems managers. At later stages, such information could be gathered and transmitted automatically through satellite or other communications links to individuals monitoring the system. This process would provide a relatively unobtrusive form of soft control.

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TABLE 1: RECENT U.S. HIGH PERFORMANCE COMPUTERS

Year	Company	Machine	Processors	Performance
VECTOR PIPELINE SUPER COMPUTERS				
	Convex	C-3 Series	1-8	34.4-960 MFlops
	Cray Research	Y-MP C-90	16	16 GFlops
		Y-MP/EL	1-4	133-532 MFlops
1992	Cray Research	Y-MP M-90	2-8	666-2664 MFlops
MASSIVELY PARALLEL COMPUTERS				
1991	Intel	Paragon XP-S	66-4096	5-300 GFlops
	Thinking Machine	CM-5	32-1024	4-128 GFlops
	Kendall Square	KSR1	32-1088	40 Mflops/node
1992	nCUBE	nCUBE 2E,2S	8-8192	27-34000 MFlops
OTHE				
1991	IBM	Power System	8-32	1280 MFlops
	Convex.HP	Meta Series		
	IBM	RS/6000 Cluster		
WORKSTATIONS				
1992	Sun Microsystems	SPARCStation10	4	400 MIPS
		SPARCStation2000	2-20	100-2190 MIPS
ADD-IN BOARDS				
1992	Transtech	TTM110	1	60 MFlops
		PARAStation	4	240 MFlops
	Sky Computers	SKYbolt	16	960 MFlops
	CSPI	Supercard Quad860	4	320 MFlops

TABLE 2: RECENT SOVIET HIGH PERFORMANCE COMPUTERS

Year	Machine	Processors	Performance	Status
1992	El'brus 3	1-16	34.4-960 MFlops	near prototype
	Elektronika SSBIS	1-2	16 GFlops	prototype
1990	MKP	1-2	1 GFlops	prototype
1988	PS-2100	64-640	1.5 Gips (32bit)	series production
1985	El'brus 2	1-10	125 MIPS	series production

AN ASSESSMENT OF THE CONTROLLABILITY OF DUAL-USE TECHNOLOGIES: OPTOELECTRONIC DEVICES

Joint Paper of the U.S. National Academy of Sciences and Russian Academy of Sciences Working Groups on Optoelectronic Devices

Alan G. Chynoweth
Vice President Applied Research and Chief Scientist (Retired)
Bellcore
Yuriy E. Nesterikhin
Kurchatov Institute
Academician, Russian Academy of Sciences
Lev N. Pyatnitsky
Department Head, Institute for High Temperatures
Russian Academy of Sciences
A. Sobolev
Russian Academy of Sciences

INTRODUCTION

Previous joint meetings between the Russian Academy of Sciences and the U.S. National Academy of Science have led to agreement regarding the general framework within which to address the question of the controllability of dual-use technologies, i.e., technologies that have both civilian and military applications. In particular, the questions concern control over the flow of imported technologies to the military (diversion) and to other countries that are not members of COCOM (proliferation).

The earliest joint meetings selected three areas of dual-use technologies for further joint study. This paper addresses one of these—optoelectronic devices.

A constant undercurrent to the discussions that took place was that controllability could not be cleanly separated from cooperation in research and technology between the two countries. While the U.S. participants focused on controllability first and cooperation second, the Russian participants repeatedly stressed (in view of present Russian economic conditions) that cooperation was their immediate priority. It is clear that both controllability and cooperation have to be addressed simultaneously.

A significant argument for taking this position is the concern of both parties over the "brain drain" of Russian scientists and engineers to potentially hostile countries, a phenomenon that is largely driven by present economic circumstances.

Thus, throughout this paper, the two threads of controllability and cooperation as they apply to optoelectronic devices are repeatedly interwoven.

OPTOELECTRONIC DEVICES AND TECHNOLOGIES

Optoelectronic devices cover a wide range of components and technologies that can be used in both civilian and military applications. The components include, but are not limited to:

lasers (semiconductor; glass; gas; chemical);

light emitting diodes;

photodetectors;

optical fibers;

optical amplifiers;

optical circuit switches;

optical scanners and imaging devices;

non-linear optical devices;

liquid crystal filters;

acousto-optic wavelength switches;

displays; holographic optical storage;

optical signal processors and computers;

and others.

In order to explore which fundamental principles might affect the achievement or otherwise of controllability, this paper will address only the components based on compound semiconductors or glass fiber technologies. Furthermore, high power devices will not be covered.

For the semiconductor devices in particular there are number of key technologies. These include:

material purification;

bulk crystal growth;

epitaxial growth (including liquid phase, metal- organo chemical vapor deposition; and molecular beam;

lithography;

patterning; and

packaging.

In addition, there is usually a need for testing equipment.

Increasingly sophisticated processing technologies are enabling the fabrication of optoelectronic integrated circuits (OEICs), which are components that combine optical and electronic technologies in a single monolithic structure to achieve specific functions (such as transmitters, receivers, regenerators, and switches, scanners and memories). The degree of functionality achievable in OEICs will undoubtedly advance with state-of-the-art technology.

Optical fiber technologies have matured considerably over the last decade. The principal fiber components are: passive optical waveguides;

optical fiber amplifiers; and

optical fiber lasers.

Relevant materials technologies include:

glass compositions and preform fabrication;

glass fiber pulling;

glass fiber coating and encapsulation; and

cabling and splicing.

Applications

Most, if not all, of the above devices and the technologies needed for fabricating them are relevant to both civilian and military applications. Civilian applications for optoelectronic devices include:

optical telecommunications;

local area networks;

computer interconnection;

optical storage (such as compact disc players);

medical equipment;

sensors;

imaging devices;

surveying;

security (surveillance) systems; and

simulation and virtual reality systems.

Military applications include:

sensors;

missile guidance systems, especially including precision weapons, with conventional explosives;
optical radar systems;
range finders;
surveillance;
communications systems, especially in airplanes and ships; and
simulation systems.

Especially for the military sector, as the ability to combine optical and electronic technologies with software advances, one can anticipate increasingly "intelligent" weaponry with on-board real-time decision-making technologies such as neural networks. Ultimately, military capability becomes measured mainly by the sophistication of the software, and the ruggedized hardware becomes essentially a commodity.

Starting from the COCOM background, the U.S. participant tended to focus initially on controlling the flow of imported technology to the Russian military. While this issue continues to be important, the discussions brought out much more starkly the concern over the re-export of technology to hostile, or potentially hostile, third countries or militant organizations. Such countries must now include at least some of the break-away republics of the former Soviet Union and perhaps additional regions as well. In addition, the potential dangers, threats, and even blackmail that could result from, for example, a few precision guided weapons falling into the hands of terrorist organizations or fanatically hostile governments can be readily imagined. Optoelectronic devices can or could play key roles in the sensing and guiding mechanisms in such precision weapons, underscoring the urgent need to establish effective control mechanisms, particularly to guard against undesired proliferation.

The conundrum that has to be tackled is that dual-use technologies cannot, by definition, be *automatically* compartmentalized from the outset into civilian and military categories—it would be a contradiction in terms. The two sets of applications spring from the same source of fundamental science and technology. But though they have a common source, there must be some points at which the two streams or innovation paths begin to diverge. The question is whether these divergence points for optoelectronic technologies can be usefully delineated.

But even if such delineation is possible, it seems rather naive to assume that the military can be prevented from acquiring any technology they are interested in. Thus, a more realistic approach may be to limit the ability of the military or the export industry to take advantage of new technology through production on a significant scale rather than by trying to achieve absolute denial of the technology. Any unauthorized production on a significant scale should generally be discoverable.

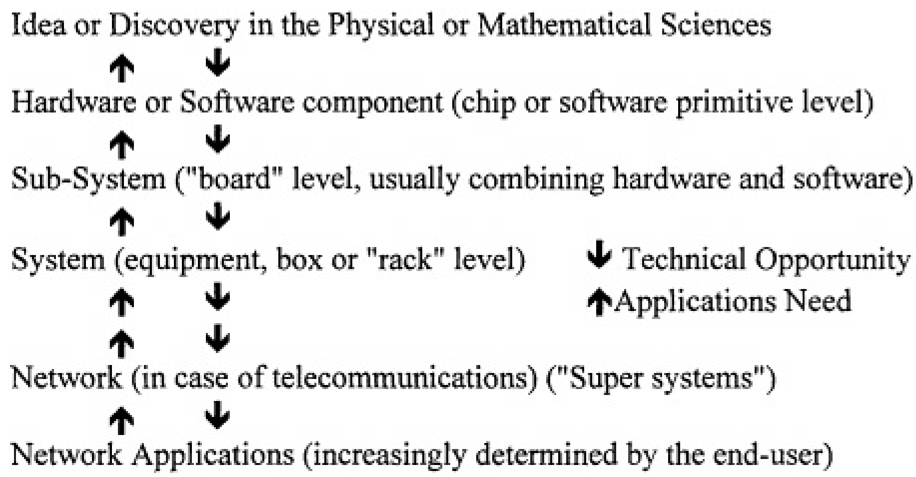
Thus, the innovation paths by which optoelectronics technologies proceed from the research laboratory to commercial or military applications have to be examined to determine which controls may be introduced.

INNOVATION PATHS

There are two familiar, interrelated sequences by means of which ideas and discoveries in the research laboratories get transformed into commercially or militarily useful products: the technical and the managerial sequences. The ideas or discoveries are sometimes the result of "pure" research, particularly in the universities and research institutes, but more often they are stimulated by a perceived or anticipated need, opportunity, or application in the marketplace or in the military sphere.

Vertical, Technical Sequence

The complete vertical, technical sequence or hierarchy that may be followed is described below:



At most, if not all, stages along the innovation paths, technology can be transferred in various forms as *products*.

The *product* associated with one stage in the sequence is often regarded as a necessary *technology* for the next stage. Optoelectronic devices are basically hardware products though they may incorporate software.

Processes are the means by which products are made or assembled. Processes may involve specialized machines, such as molecular beam epitaxy machines or electron beam synchrotrons.

Also, know-how is generally crucial but often abstract. It resides in the minds and skills of individuals.

Hardware products and specialized machines lend themselves to various control procedures, especially if they are fairly large and/or relatively few in number. The know-how that individuals possess underscores the importance of alleviating constraints, financial, environmental, etc., that could otherwise incline valuable individuals with sensitive knowledge to emigrate to non-COCOM countries.

Horizontal, Managerial Sequence

There is also a horizontal or managerial sequence (pictured below) that can be followed for each step in the above sequence:

Idea or discovery (Responsive or Creative)
↓
Proof of concept or feasibility demonstration (Research resources)
↓
Design of prototype and field test (Development resources)
↓
Scale up for manufacture (Manufacturing resources)
↓
Marketing, distribution, and maintenance (Sales and Service resources)

In our discussions, the point was repeatedly made that the managerial sequence offers a number of possible control or "choke" points, particularly at interfaces between various organizations or institutions. There are also a variety of control techniques that can be considered at various points along the innovation path, including techniques that are becoming increasingly familiar in the commercial world for such tasks as inventory tracking.

In assessing the controllability that can be exercised over optoelectronic devices, these two sequences—the technical and the managerial—should be kept in mind.

CONTROLLABILITY CONSIDERATIONS FOR OPTOELECTRONICS

Fundamental Science Phase

The way the world-wide research community operates and communicates effectively keeps researchers all over the world very much informed about significant discoveries, ideas, and results. Lead-times enjoyed by the originators are seldom more than a year, often very much less. The spirit of open communication between researchers has deep roots. Many times even a rumor over the "grapevine" that another scientist has achieved a certain result serves to stimulate other scientists to come up with an equivalent result using their own ideas and ingenuity. And nowadays, the operation of the grapevine has been greatly enhanced by the evolution of worldwide networking of researchers over Internet.

For commercial purposes, critical inventions can be patented, thereby giving the inventors certain commercial rights and advantages if all parties and countries are playing by the same rules. It is critically important, therefore, for Russia rapidly to establish intellectual property laws that are in line with those operating in the COCOM countries.

Bureaucratic control over intellectual property *in itself* is not likely to completely prevent unauthorized military or other applications, but it is an important element in Russia's strategy for developing mutual trust.

CONCLUSION

Both Russia and the United States can learn from each other but it is unrealistic to assume that either Russia or the United States possesses an overall intellectual advantage at the fundamental science level because of the long-established modus operandi of the world-wide research community. Indeed, the open cooperation between Russian and American scientists at this level should be encouraged as a means by which Russia will become better integrated into the world economy. Furthermore, such cooperation tends to counteract the brain drain problem.

Cooperation already embraces such mechanisms as: scientific exchanges; direct support of science centers in Russia; support for participation by Russian scientists in American conferences; and, perhaps most importantly, well-managed collaborations between peer groups with well-defined goals in important areas of fundamental science. It is important to recognize that in addition to financial support; Russia particularly needs support in the acquisition of managerial practices appropriate for applying science to a civilian economy. Joint projects provide opportunities for Russia to acquire more of such expertise.

Optoelectronic Device Fabrication Phase

RESEARCH PHASE

To transform fundamental physical and device concepts into actual demonstrations, working models, etc. often requires special skills, materials and equipment. For research demonstrations, Russia's long-standing capability in materials and compositions is generally sufficient, only a few people need to have the skills, and only a small amount of equipment (maybe one of a kind) will often suffice. Russia can nearly always provide such levels of support. Relative lack of equipment resources can stimulate extraordinary ingenuity in order to achieve the desired result. Russia ingenuity under adversity is outstanding. And when domestic resources cannot meet the need for some advanced fabrication equipment, such as, perhaps, for fine line lithography, it has to be assumed that Russia can acquire an example from the West.

CONCLUSION

Russia has, or can acquire, the small amounts of technology it needs in order to perform research demonstrations. The only exception at present for optoelectronic devices might be in the area of sub-micron lithography of compound semiconductors, especially for the fabrication of advanced OEICs. Thus, except in very few, highly specialized cases, it would seem almost impossible for COCOM to deny Russia any access to state-of-the-art optoelectronics technology at this research phase. It should be noted, however, that individual commercial enterprises will decide for themselves which of their proprietary technologies they will make available to Russia and which they will continue to hold proprietary for perceived commercial advantage.

TECHNOLOGY TRANSFER AND SCALE-UP PHASE

In this phase, technology transfer from the research demonstration to a production design and to manufacture occurs. Though America's abilities in this regard are not perfect by any means, this is probably the area to which Russia has to devote most attention at present if it is to become an effective participant in the world economy. These transfer steps also offer various opportunities for exercising control over where dual-use technologies are applied.

Russia has long had an impressive indigenous military capability. While in areas of new technology it has generally lagged behind the United States, the lag has been a matter of only a few years. Clearly, where commercial metrics do not matter, Russia has been able to transfer technology out of the research laboratory or institute and into production facilities for the military. While the U.S. author has no knowledge of Russia's military uses of optoelectronics, it would seem safe to assume that Russia is able to mount adequate development and production to meet military needs.

It is likely, however, that the present *productivity* of these military production facilities is significantly below the levels achieved in the United States and other Western countries. Conversion to commercial production, as well as meeting the worldwide marketplace's criteria for costs, timeliness, reliability, performance, and customer appeal, are likely to require considerable assistance from the West, especially as regards organization, management, and marketing practices as well as with modem production equipment. Russia recognizes this need, as evidenced by the high level of activity in Russia of Western management consulting firms.

Special equipment needed for the production of optoelectronics devices may offer effective opportunities for exercising control, either by denial or by monitoring its use.

The above remarks apply particularly to the fabrication of optoelectronic chips and their packaging to make components. It can be expected that production capability in Russia will catch up fairly quickly to the West in discrete components but will tend to lag behind the West when it comes to OEICs. It should be pointed out, however, that OEICs are still largely in the research phase even in the United States, underscoring the complexity of the technology and perhaps also reflecting on questions as to how the technology will be best used or made competitive with simpler, hybrid technologies. Thus, OEICs could well afford Russia the opportunity to catch up substantially with the United States by the time they become commercially important.

CONCLUSION

The military in Russia will get the technology it needs whether or not the West provides technical assistance. But the West, in helping Russia towards a market-based economy, will inevitably make it easier for the military to get what it wants, and more quickly. The challenge to the West, as in any competitive enterprise, will be how to keep always a few steps ahead of Russia's technology, particularly as regards applications of the technology. Control by denial of advanced optoelectronic technology to the extent it can be exercised, is most likely to be in the few special fabrication, packaging, and testing technologies, if any, where the United States has a distinct competitive edge and can therefore maintain a lead time.

The challenge to both Russia and the West is to ensure that Western state-of-the-art optoelectronics technology acquired by Russia through the course of research collaborations does not make its unauthorized way into the hands of the military or, even more important, the hands of potentially hostile nations, regions, or organizations.

Russia's scientists are well aware of their responsibilities as regards the prevention of unauthorized diversion or proliferation of technology, as was repeatedly made clear in the discussions. They are aware that breaches of agreements regarding technology transfer could seriously jeopardize, even destroy, the international cooperation that is so important to Russia.

Russia's scientists in the Academy institutes believe they can exercise considerable control over what optoelectronics technology transfers take place between their institutes and industry- or defense-oriented institutes. However, this ability to control needs to be demonstrated. One of the best ways of doing so is for American scientists to work with Russian scientists on joint projects in their research institutes. Such close cooperation helps achieve multiple objectives: the transfer of American technology and know-how to Russia and vice versa; increased knowledge or awareness of the uses of technologies under development in Russia; and, thereby, building an atmosphere of mutual trust.

However, even if the scientists in the research institutes can exercise effective control over the initial transfers of technology out of their institutes, their ability to control subsequent transfers between other organizations is likely to be considerably less. Russia clearly recognizes this concern, as evidenced by its current approach to establishing two export control (or restriction) lists—one for science or research and the other for applications or products, the latter applying to industry and defense institutes. Clearly, Russia's scientists are involved, along with representatives of industry and the military, in generating these lists. Likewise, they can be influential in recommending any other control mechanisms and government structures for establishing necessary controls and monitoring procedures.

Incorporation of Optoelectronic Devices in Equipment

In the foregoing, optoelectronic devices and the technologies for fabricating them have been regarded as essentially generic in nature, equally applicable to both civilian and military applications (dual-use). But at this point, differentiation between various types of applications may begin. While there may still be a lot of commonality between, for example, optical communications equipment needed for public telecommunications networks on the one hand and for military local area networks on the other, the particular special requirements posed by the two sets of applications begin to be more evident. While the military applications will typically emphasize performance and reliability of the equipment, civilian applications will *also* place more emphasis on customer appeal, competitive cost, and timing (to hit the market "window"). Different sets of equipment therefore begin to emerge, although based on a common optoelectronic technology.

However, having identified optoelectronics devices as a generic, dual-use technology, care has to be exercised to ensure that not ALL optoelectronic devices are mistakenly and automatically lumped under the heading of dual-use. There may be some devices which, by virtue of their unusual performance parameters or their ability to work in extremely hostile environments, are relevant to military applications but otherwise have no practical relevance for commercial applications. Such devices, and any special materials and processes needed to make them, would clearly belong on the control or restriction lists currently being compiled or updated and should not be regarded strictly as dual-use.

Two possible sources of the generic optoelectronic components have to be recognized: direct purchase from the West (paid for, for example with hard currencies earned from export of oil or other natural resources); and domestic production, with or without the help of the West.

Likewise, at the equipment level, sources can be foreign or domestic. Production facilities can be established and/or operated in Russia with or without Western help, though the latter's expertise would undoubtedly expedite the process.

CONCLUSION

In view of the multiple potential sources of optoelectronic components and technologies, control at this level by denial would be very difficult if not impossible for the West to achieve. (Vast quantities of optoelectronic components can easily be carried in a briefcase.) It would be a little easier at the optoelectronic equipment level, and with specialized production and testing equipment, because of the greater visibility and smaller number of these products. On the other hand, equipment is generally quite readily reverse-engineered. Control by denial therefore would be at most a delaying tactic and at the same time would deny market opportunities to the United States.

Inventory Tracking and End-Use Verification

As the foregoing discussion has brought out, except in very few instances, control by product denial is generally not feasible, whether at the technology, component, or equipment level, and furthermore, often runs counter to the larger objectives of assisting Russia towards a market economy.

Another, and in many ways more attractive, approach towards achieving a degree of national security (and international stability) may be keeping track of products through some form of automated inventory information base system. Such systems, such as those based on bar codes and bar code readers (using optoelectronic devices) are now widespread in business and commerce. They lend themselves to a variety of information analysis and intelligence deriving techniques.

Inventory tracking at the chip level would require some internationally agreed-upon method of marking the chips, e.g., by including a bar code, trademark, or other indicator in the lithography step. Whether such an approach would be feasible or effective must be assessed separately.

Inventory tracking at the board and equipment levels is certainly feasible—it is already widely practiced in industry. Again, international agreement needs to be reached on how to mark boards and equipment, including production equipment as well as finished products, but bar code marking appears to offer many advantages.

CONCLUSION

With the advances being made in data base management and analysis, such marking techniques have several attractions. They would allow verification of the origins of products and, if well implemented, identification of illicit products or end-uses and unauthorized copies. They could perhaps reveal anomalous production levels, inconsistent with the verified end-uses and suggestive of diversion to military uses or illegal fostering of exports to other countries (i.e., proliferation). On the other hand, ways in which such a control scheme could be circumvented by unfriendly parties should be thoroughly addressed.

Implicit in a universal, internationally agreed marking scheme is the creation of an international center for implementing and managing the information base and for deriving intelligence from it. Such a center might be under the auspices of the United Nations or, at a minimum, under the auspices of the COCOM-signatory countries.

OPTICAL COMMUNICATIONS

Probably the most urgent civilian application in Russia for optoelectronic devices is in optical telecommunications. The United States and most other technologically advanced countries have deployed long distance systems widely and are now addressing the deployment of optical systems in local distribution and cable TV systems. Thus, these countries are establishing ubiquitous, broadband public networks. These networks are regarded as vital for a modem economy and industrial competitiveness.

These broadband networks are also of strategic value to the military. In the United States, because of the enormous investment required and the rapidly advancing sophistication of civilian technology, the military increasingly relies on standard civilian technology to meet its needs. This is a reversal of earlier policies which tended to stress, whenever possible, spin-off of advanced technologies from the military to the civilian sector.

Thus, broadband telecommunications networks in the United States are becoming a dual-use systems, or supersystem, technology. Virtually every civilian application of the optical technology has a military counterpart, as seen in the following hierarchy from largest to smallest:

Civilian Technology	Military Use
Submarine cables	Underwater surveillance, detection
Long distance terrestrial systems networks	Strategic, global or regional networks
Local feeder	Tactical area networks, military base complexes
	Information processing, shipboard and aircraft systems
Local area networks and data links	High-performance computers ("board level")
	Special performance ("chip level")
Optical interconnection	Missile guidance, night vision
OEICs	
Devices (LEDs, lasers, photodetectors)	

In addition, while free space optical communications have relatively specialized applications, such as in police radar and building security systems, they are fundamental to many tactical or battlefield uses by the military.

Some of the items in the above list especially optical interconnects and OEICs—are still largely in the research or exploratory development phase and have not yet made their way into standard civilian systems.

The first item, submarine cables, is a thriving worldwide business at present, but it seems likely that Russia has very little domestic need for such systems.

First generation long distance and local feeder systems are by now very much a commodity. They are based on discrete (not integrated) optoelectronic devices and single-mode fibers based on well-established technology. Understandably, Russia does not wish to invest in less than state-of-the-art networks, but these first generation networks are what the United States and other countries are investing in for *their* public networks.

Later generation networks may be based on optical solitons (under serious consideration for submarine cable and perhaps long haul), coherent optics, or multiple wavelengths. The latter in particular are being actively pursued for high volume information traffic handling. But all of these systems and their components are still very much in the research or exploratory development phase and are not yet ready for widespread commercial use. Eventually they are likely to lead to higher performance, higher capacity optical communications systems but they are not relevant to Russia's current need to upgrade substantially its telecommunications infrastructure.

Contemporary civilian technology is increasingly based on the internationally accepted SDH (Synchronous Digital Hierarchy) or SONET (Synchronous Optical Network) standards. Equipment operating up to 632 Megabits/sec is becoming commonplace. As the performance of individual components is raised, the speed of the networks gets to be several Gigabits/sec, with systems operating at 10 Gb/s now a well-established objective. But if pressed, a user such as the military does not have to wait for faster components to be developed; multiple slower channels (e.g., 632 Mb/s channels) can simply be bundled or multiplexed together, albeit at lower efficiency and greater cost.

The need for such ultra-high performance systems is not likely to be felt by the civilian economy in Russia for quite a long time. Putting in supersystems only makes economic sense if there are enough workstations, supercomputers, and video and multimedia services requiring them. The traffic justifications for such systems take a relatively long time to build up even in the United States.

High performance hardware is only a first step towards a modem high performance optical communications network, whether for civilian use or for military C^3I applications. As a first step, optical fiber is simply substituting for a lot of copper in order to achieve bandwidth. But key to the performance, flexibility, adaptability, and robustness of future networks is the overall network architecture (so-called intelligent networks) and the software systems for operating and supporting these networks. Such architectures for public networks are, perforce, public knowledge, but the equipment and the software systems contain much that is proprietary.

For C^3I applications in times of combat, theater operations will require massive information transmission and processing capabilities calling for the very highest performance workstations, microprocessors, computers, and information storage and retrieval systems. Optical signaling processing is expected to play an important part, eventually, in handling and analyzing, in real time, massive amounts of information and providing guidance to equipment and/or personnel. But such demands seem at present to be well beyond the needs, actual or anticipated, of basic, high quality civilian telecommunications networks.

CONCLUSION

Optical telecommunication systems based on discrete components are state-of-the-art and are currently being deployed commercially world-wide. Performance at hundreds of Mb/sec is now standard and some commercial systems performing up to several Gb/sec are imminent. Fiber optical amplifiers are also about to enter the commercial marketplace. Soliton, coherent optics, and wavelength switching systems are currently in the research or exploratory development phase.

Systems for which Russia may not have significant civilian need at present but which have considerable relevance to the military include submarine cables and high power laser-based systems, particularly free-space systems.

At the component level, the most sensitive areas from America's perspective would be integrated components providing enhanced functionality, especially "intelligent" components for information processing, specially hardened or ruggedized component structures and packages, and individual devices that can be used in telemetering, sensing, and image processing systems for precision guidance and delivery of missiles and other munitions.

Sensitive areas at the systems level include the so-called intelligent systems based on sophisticated combinations of software and hardware architectures, but so far optoelectronics has not had a major impact in this area.

With respect to all of the above technologies, components and systems, as well as other optoelectronic devices and the means for producing them, the present COCOM lists need to be reviewed and, where appropriate, updated. Particular attention should be paid to where performance parameters may be used to distinguish between civilian and military applications, such as wavelength ranges and upper limits to speed, bit rates, and power. (It should be noted that the fact that an item is on the COCOM list does not necessarily mean that its export will be denied. Export may indeed be approved provided there are safeguards in place to ensure that the items do indeed end up in the agreed civilian applications.)

OVERALL CONCLUSIONS

While the emphasis in this paper has been almost entirely on the flow of American technology to Russia, there are many situations where the flow is in the reverse direction. It is also accepted that America's interests and the cause of world peace are served for the foreseeable future by Russia's progress towards a market economy. The implication of this policy is that its success will be apparent when Russia is regarded as a fully-fledged, capable competitor in the global marketplace. In turn, this implies that Western technological and managerial expertise, particularly for scaling up to commercially viable and timely production levels, will infuse Russia in much the same way as it has spread among the Western and Pacific Rim countries. This phenomenon is itself a manifestation of international commercial competition and it is in America's interest to be prominent in the spread of expertise into Russia just as it has been among other countries.

American corporations are extending themselves into Russia in various ways. At present, this cooperation is mainly at the research level but it can be expected to expand into the design, development, and manufacturing phases, as well through such approaches as specific contracts and joint ventures. These activities will be focused at first on upgrading Russia's economy and standard of living, particularly through the build up of its internal markets.

An essential feature of an upgraded economy for Russia will be a modern telecommunications infrastructure. Optoelectronics technology can be expected to play a major role. Russia will not be able to purchase *all* of its optical telecommunications equipment from abroad, although it will certainly purchase some early systems in order to get started. But *Russia* will need to establish its own world class telecommunications equipment production facilities to help meet the country's enormous needs. Western expertise, among which the United States must be counted, is urgently needed to establish commercially viable equipment development and manufacturing facilities, particularly through the conversion of industries previously focused on supplying the military forces. Furthermore, as a practical matter, very little in the way of optoelectronics technology or managerial or operational expertise will or can be withheld or denied by the West.

Russia already has the essential intellectual and basic research capabilities. With improved facilities, Russia will be able to strengthen the coupling of its research to development and production. Control from the West of these internal operations will not be feasible let alone desirable. Likewise, with the inevitable infusion of Western market research, marketing, sales, and services capabilities, Russia will eventually be able to manage the total innovation chain, from basic research to the commercial marketplace, and vice versa.

The concern for the West for the near-to-medium term future is how to ensure that diversion of Western technology to military purposes or, perhaps more seriously, to "unfriendly" countries and organizations does not occur.

The best, though by no means foolproof, managerial mechanisms for keeping informed as to how state-of-the-art technology initially is used will be derived from close, day-to-day cooperation and collaboration between Russian and Western scientists and engineers on research programs of common interest. Such collaborations, starting in the least sensitive areas, can steadily build mutual trust and allow incremental progression into collaboration in increasingly more sensitive areas.

The best technical mechanisms for minimizing diversion and/or proliferation appear to be based on marking techniques, such as bar codes and data bases for keeping track of optoelectronic equipment, including production equipment imported from the West or constructed using Western expertise. Records kept in this way would have to be verified from time to time, such as by customs inspectors and by unannounced inspections of facilities and production and shipping records. (It is unlikely that any significant production or distribution to users can occur without records.)

Going beyond joint bilateral cooperation would suggest the establishment of a multi-nation inspection activity, perhaps under the auspices of the United Nations, focused on international trade in particular items of military technology. The world may not yet be quite ready for this step, but it might be logical to begin discussion of such an international inspectorate.

Since Russia seeks the benefit of Western technology and managerial know-how, it will be careful to operate within the rules mutually agreed to. Trust is essential. Any violations revealed by the operation of the inventory tracking information base could damage this trust, leading to subsequent denial of further assistance. Likewise, it will be in American's interest not to violate the mutually agreed rules where the United States acquires technology and technical know-how from Russia.

IMPLICATIONS FOR INTERNATIONAL COOPERATION

The foregoing essay obviously assumes a considerable amount of international cooperation among Western and "fully-cooperating" countries on one hand, and between this group and Russia on the other. Cooperation would at a minimum have to address the following topics (though these are by no means unique to optoelectronics):

- Russia is already working expeditiously on establishing a framework of laws, regulations, and penalties with respect to rights and obligations regarding intellectual properties, patents, and licensing procedures. International acceptance of this framework needs to be reached.
- Russia, under its newly formed Export Council, is already developing restriction lists for both science and products for use in controlling exports (proliferation). These restriction lists and the existing COCOM lists need to be made as much the same as possible. It is also appropriate for the COCOM list to be reviewed and, where appropriate, updated.
- It is recognized that there is urgent need to provide Russia's scientists with support and expertise appropriate for transition to a civilian economy, not least of all to discourage or even eliminate emigration of scientists to potentially unfriendly countries. Mechanisms for such support and the obligations of all parties with regard to research collaborations must be widely understood and accepted. Collaborations on joint projects are felt to be particularly effective for developing mutual trust—by increasing understanding of each party's needs and obligations, and by increasing sensitivity to, and awareness of, ways in which new technology is being, or may be used. In particular, research collaborations may offer opportunities for monitoring, even controlling as "choke points," the transfer of technology out of research institutes into industry or military establishments. Research collaborations and joint projects should start in least sensitive areas and incrementally progress to more sensitive areas, as appropriate, as mutual trust builds with experience.
- The effectiveness of export and re-export controls can be greatly facilitated by a practical marking scheme for components, products, systems, and key production and testing equipment. The well-established bar code system for inventory tracking might well be adopted to fulfill this role. It may even be possible to use it at the individual device or chip level. Its successful implementation, however, requires international agreements on standard bar codes and monitoring procedures.
- An international organization or center needs to be established to gather information on technology flows and to verify end users. This center should be equipped with state-of-the-art information monitoring and analysis techniques designed to detect unauthorized or undesirable transfers or exports of technology and other possible violations of international agreements. Customs and other law enforcement agencies must be trained to detect attempts at illicit transfers of technology.

In short, as has been proposed by others, an approach to controlling sensitive technologies consists of three steps:

1. *Establish Agreements*;
   Governments must first reach agreement with each other as to what needs to be done;
2. *Build Trust*;
   Particularly by working closely together to jointly implement the agreements;
3. *But Verify*;
   As in any responsible business enterprise, audits must be regularly performed to ensure that the system is working and that agreements are being kept.

ENDNOTE-SOME EXAMPLES OF POSSIBLE OPPORTUNITIES FOR RESEARCH COLLABORATIONS IN OPTOELECTRONICS

While the discussions focused primarily on general principles relating to the preventing the diversion or proliferation of militarily sensitive technology, a number of examples were suggested by the Russian authors of opportunities for research collaborations between Russian and Western scientists. The following list gives these examples, but it clearly is not exhaustive, nor probably even representative. However, it should serve as a stimulus to Western scientists and research organizations to be more proactive in assessing the mutual benefits that might result from increased attention to these opportunities for international research collaborations.

It should be noted that there are already two collaborative programs in operation in optoelectronics between AT&T Bell Labs and Russian institutes on optical fiber technology (General Physics Institute) and semiconductor lasers (Ioffe Institute).

Other opportunities for collaboration suggested by Russian participants in the discussions included:

- laser disc memories;
- magneto-optical information storage;
- semiconductor laser structures;
- 'table-top' laser systems;
- electronic image converters;
- plasma accelerators (high-power lasers);
- optical image simulation technologies;
- use of electron synchrotrons for fine line lithography;
- nanotechnology;
- information networking and multi-media services over optical networks; and
- optical computing elements using laser and optical amplifier arrays.

AMERICAN CONTRIBUTION FOR THE JOINT PAPER OF THE U.S. NATIONAL ACADEMY OF SCIENCES - RUSSIAN ACADEMY OF SCIENCES WORKING GROUP ON STRUCTURAL (FUNCTIONAL) MATERIALS*

Dr. Robert A. Sprague
Division Staff Engineer
Aircraft Engines
General Electric
Dr. Albert C. Westwood
Vice President
Research and Technology
Martin Marietta Corporation

INTRODUCTION

With the end of Cold War, the relations between the United States and the Russian Federation have become less adversarial on many fronts, from foreign policy to commerce to science and technology. The hope is that the two countries' basic principles and goals have drawn closer. In this context, some of the key features of the Cold War, such as the regimes governing the export of sophisticated dual-use technology from West to East and from North to South, should be reviewed and possibly modified.

At the heart of the issue are questions of which technologies or uses should be controlled and which technologies can practically be controlled in terms of their manufacture and proliferation. Controllability depends strongly on the nature of the technology, its availability on global markets, and the organizational arrangements governing its use and distribution.

In the past, control efforts have consisted of measures taken by the United States and its allies in the Coordinating Committee for Multilateral Export Controls (COCOM) which assumed active attempts by agencies of the Soviet Union to divert sophisticated technology. Organizational arrangements range from product control lists, extensive export licensing procedures and strict enforcement mechanisms, to rigid physical controls

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over individual installations in the destination country. Simultaneously, the Soviet government took very similar measures to prevent advanced technologies from being obtained by the U.S. and its allies. Reliance on mutual cooperation was minimal.

In recent years, remarkable progress has been made in recasting diplomatically the relationship between the U.S. and the Soviet Union/Russia from one that has been fundamentally confrontational to one that is more mutually beneficial. The cooperation of Russians can be a powerful factor in the export control equation. If the Russians can demonstrate their ability and willingness to work with Western governments, vendors, and users in keeping sophisticated technologies from being diverted to military uses or restricted destination countries, it is possible that the iron-clad controls of the past can be eased to the benefit of commerce, scientific progress, and the Russian transition to a viable market economy.

In any relationship, including that between countries, the reduction of confrontation does not lead immediately to an establishment of trust. The latter can be accomplished only through the multilateral establishment of procedures and mechanisms to achieve the goals of non-diversion and non-proliferation, and a series of small and incremental steps taken over time in which both parties demonstrate trust, trustworthiness, and a willingness to work together in mutually beneficial ways. These will necessarily involve an element of risk, since measures which give one party complete control over the actions of the other give the latter no opportunity to demonstrate independent good faith and cooperation. Russians must be given the opportunity to demonstrate they are both willing and able—in both theory and practice.—to respect the national security concerns of the United States and to cooperate in preventing the diversion and proliferation of sophisticated technologies, provided the United States does the same.

In the past, the Soviet Union's willingness to control diversion and proliferation was questioned, but its ability to do so was not. Strong, centralized political and military institutions effectively regulated sensitive technologies. Today, there is reason to suspect that although Russia's willingness to control proliferation has increased, its ability to do so has decreased. Partly as a result, concerns about North-South proliferation of technologies to such countries as Iraq and Iran have grown. It is largely incumbent on the Russians to demonstrate to the Western community that effective, civilian control regimes can be established in spite of widespread fragmentation and decentralization of lines of authority.

This paper examines the preset nature and inherent controllability of high performance structural materials (HPSM) and their enabling technologies. It addresses means of control in the context of broader efforts to create an environment in which the need for control is reduced.

HPSM DEFINITION AND DISCUSSION

HPSM are defined as *dual-use capability materials used for either mechanical integrity or because of their unique functional capability, e.g., electronic materials*.

The main goal of the Russian Academy of Sciences in close cooperation with the U.S. National Academy of Sciences in the field of a strategic materials science is an overview of the research carried out on HPSM of both organic and inorganic nature over the following groups of functional properties, namely:

1. Functional ceramics and ceramics composites, including

   - high temperature superconducting ceramics,
   - optic ceramics,
   - near-zeroth expansion coefficient ceramics and ceramic composites.
   - micro- and optoelectronic and electrotechnical ceramics and ceramic composites for substrates,
   - ablating ceramics and ceramic composites;

2. High performance refractory metal alloys;
3. High temperature capability/highly oxidation resistant alloys and composites;
4. Lightweight/high temperature capability intermetallic and composites components;
5. Metal matrix composites;
6. Carbon/carbon structures;
7. Resin matrix composites of over 300ºC capability (thermostability enhancement additives and stabilizers);
8. Electronics of organic materials, including

   - organic and elementoorganic ferromagnets; composites; coatings, devices, and instruments with their application;
   - polyfunctional polymers, conducting polymers and their composites, carbon containing materials, and clusters;
   - second and higher order non-linearity materials - molecular and polymeric;
   - gas transducers based on organic semiconductors, transducers of physical values and radiation;
   - oligo- and polyorganosilsesquioxanes and elementoorganosilsesquioxanes binders and film forming materials;
   - synthetic metals and organic superconductors;
   - theoretical investigation and design of organic functional materials;

9. Molecular electronics, including

   - biomolecular sensors;
   - molecular electronic elements;
   - langmuir-Blodgett films and layers;

10. Inorganic and organic materials for high performance non-linear optics; and
11. Directional and single crystal components.

All these branches of material science evidently have the highest impact on the effectiveness (especially in the targeting of high precision guided munitions), performance, reliability, and specific mass gain in defense systems. However, cost considerations keep these technologies substantially out of widespread application in civilian branches of industry despite their many functional properties, such as electromagnetic pulses protection, effective radio-frequency radiation absorption, the highest selectivity and sensitivity to changing environmental factors, high transparency and high nonlinearity, fast response, etc. Given a reduction in cost, these technologies may be of the highest prospective value for civilian production. Such highly classified technologies have had a decisive impact on the defense potential of both countries. Therefore, any proliferation of them may have a major influence on the of development of armaments in the third world.

High performance structural materials (HPSM) are developed for and deployed in strategic applications such as launch and re-entry vehicles, satellites, subsonic and supersonic aircraft (particularly gas turbine powerplants), ground based air and space monitoring systems, and to a lesser extent, process equipment used to manufacture and support these systems. Materials research and development in major power countries has for four decades been a cornerstone of their national defense strategy.

Characteristics of HPSM

HPSM are characterized as those having application benefit generally not attainable with materials such as conventionally wrought iron, nickel, and tin alloys. Products containing HPSM offer advantageous performance advantages over systems containing conventional alloys. This is particularly true for military aerospace systems, but it is also relevant to commercial systems such as gas turbine engines.

HPSM, because of their intended use, must also possess high reliability or, at a minimum, service life predictability. This characteristic generally requires an invention (or established laboratory feasible) to product application cycle of at least seven years. The effort during this period is related mainly to reliability realization as opposed to capability enhancement. Examples are the invention and reduction to practice of processing methods such as isothermal forging or directional casting, methods of obtaining high purity, and uniform fiber alignment.

HPSM Products Enablers

In addition to the product enablers cited above, it is often necessary to develop attachment methods for joining non-fusion weldable or reconciling differences in thermal expansion properties. Diffusion bonding, high temperature adhesives, and low fusion processes such as laser technology are therefore an integral part of HPSM product realization.

These requirements cascade into a second tier of required capabilities such as process monitoring and control, process sensor technology and process thermal management.

Also integral with HPSM realization is the design technology that enables benefit from their deployment. Low ductility, anisotropic properties, and mechanical attachment to dissimilar materials are examples of the system's required design expertise.

Thus, the development of the enabling process and design technology that enable product benefits to be realized is characteristic of HPSM.

HPSM Technology Acquisitions

HPSM generally are acquired integrally with the system in which they are installed. While the removal and integration of these materials tell one much about their form and function, little can be learned relative to their manufacture and design features. However, when systems are deployed together with repair, maintenance and spare parts acquisition rights, much technology relating to HPSM can be gained. Transfer of capability to produce HPSM, such as single crystal airfoils, results in even greater, but not total, knowledge transfer. Total technology transfer would occur in the event that two parties agree jointly to design, develop, and deploy systems or sub-systems containing HPSM. Note, it is possible to develop large systems containing HPSM if the party with the HPSM knowledge produced the sub-system containing the HPSM. The coupling of these sub-systems into a complex device does not by itself transfer HPSM capability to the second party.

This report is the result of extensive collection of data from academic institutions and their collaborators in industrial organizations that employ dual-use materials science technologies. It is aimed mainly at the following problems:

- Evaluation of the collected information from the point of view of dual-use technologies, i.e., their potential value for civilian applications and the potential danger of their proliferation on the level of know-how, existing apart from published results; and
- Presenting some recommendations for support and/or joint research in the above fields, with the goals of minimizing "brain-drain" while improving global prosperity.

Framework for Confidence (Trust) Building

Nowadays basic scientific knowledge diffuses extremely rapidly, and national boundaries are essentially transparent to such flows. On the other hand, specifics of discoveries and engineering knowledge, i.e., the information required to transform profitably a concept into a product, tends to be less mobile. There are several reasons for this: the knowledge exists as know-how in the minds of the practitioners and crucial details are not written down; industrial engineers tend not to travel or present papers at scientific conferences; patent protection via a fenced portfolio makes unauthorized use difficult and potentially expensive, and the production process is likely to utilize equipment that is not readily available and is complex in operation.

For this and other reasons, it has been evident for some time that controls on the exploitation of advanced technologies probably are best applied at the design, manufacturing, and distribution phases, rather than in early basic R&D stages. This recognizes that there is scarcely any technology that cannot be utilized under given conditions for both peaceful and military purposes, be it radar, communications, biotechnology, or whatever. This is especially true for HPSM.

Materials likely to be candidates for diversion to military purposes, however, are likely to exhibit certain distinctive characteristics, e.g., high strength, excellent corrosion anisotropic resistance, durability at high temperature, anisotropic property, specific coefficient of thermal expansion, superior function-to-density ratio, etc. Such properties are a consequence of a precisely controlled chemical composition and some specific and reproducible process that together result in a homogeneous or predictably in-homogeneous microstructure. Increasingly, nowadays, such microstructures are multiphase and of micron scale or less.

Our Russian colleagues inform us that the following Russian Academy of Sciences institutes are leaders in materials science: Department of Electronics of Organic Materials, RAS, Moscow; Institute of Electrochemistry, RAS, Moscow; Institute of Organo-Element Compounds, RAS, Moscow; Joint Non-Linear Optics Laboratory of Electrophysical Institute, Ural Division of RAS at Technical University of Chelyabinsk, Chelyabinsk; Institute of Spectroscopy, RAS, Troitsk, Moscow Region; Institute of Organometallic Compounds, RAS, Nizhnii Novgorod; Institute of Crystallography, RAS, Moscow; Institute of Solid State Physics, RAS, Chernogolovka, Moscow Region; Kazan Physical Technical Institute, RAS, Kazan, Tatarstan; General Physics Institute, RAS, Moscow; Institute of Chemical Physics, RAS, Moscow; Ioffe Physical-Technical Institute, RAS, St. Petersburg; Shemyakin Institute of Bioorganic Chemistry, RAS, Moscow; Kapitza Institute for Physical Problems, RAS, Moscow.

In a separate paper, our Russian counterparts propose a program on electronics of organic materials and a study on the multicomponent functional optic ceramics based on metal fluorides.

HPSM Control

Options for the control of HPSM necessitate consideration of the flow for manufacturing and distribution of these materials. This logic permits identification of certain opportunities for the monitoring and control of High Performance Structural Materials.

1. Chemical Compositions: The production of HPSM generally requires that composition be controlled to extremely close tolerances. The presence of even a few parts per million of a specific impurity can markedly reduce performance, e.g., by causing segregation at grain boundaries that lead to embrittlement. Thus, one indicator of the likelihood that the intended product is an HPSM is the need for starting materials of ultra high purity (>99.99% pure). The preparation of such pure materials is non-trivial. It requires special equipment, the purchase of which can be noted, its location identified, and its usage monitored, perhaps on a random basis.

   Another leading indicator for the manufacturing of HPSM's is the use of specific, property-enhancing alloying elements, usually non-commodity materials such as boron, hafnium, ultra fine carbon fibers, etc. There are likely to be only a limited number of sources for such materials, so they, too, can be monitored.

   The requirements for the prevention of contamination during processing is a further indicator. This is likely to require the use of specific high purity refractory materials for melt containment and high purity inert gases to minimize oxidation during melting or heat treatment. Thus, monitoring the manufacture or purchase of highly pure materials, both as elements and as products (e.g., refractories), should provide a useful start towards limiting the unapproved production of HPSMs.
2. Processing Equipment: The processing of HPSMs also requires equipment capable of precisely controlling temperature (to +5ºC at 1550ºC, for example), pressure, and working atmosphere, etc. The location of all such equipment should be recorded, and its operation routinely monitored.
3. Manufacture of Useful Shapes: The benefit of the extraordinary properties of HPSMs, such as super strength and hardness, usually carries with it the penalty of making them difficult to manufacture. Shaping HPSMs can be tedious. Machining or grinding is slow and expensive, and joining is likely to require special procedures such as electron beam welding, explosive compaction, or advanced adhesives. Additionally, the end product will require sophisticated non-destructive analysis. All of these peculiarities provide opportunities for control.

   The cost and difficulty of shaping HPSMs has led to the trend towards the production of "near net shapes." Preferred ways of making these are by precision casting, or the hot-isostatic pressing of ultra fine powders. Equipment for such processes is not yet common, and is likely to be available from only a limited number of sources, which also facilitates control.

4. Product Distribution: Assuming that certain HPSMs can be produced without approval or detection, the next concern is to prevent distribution to inappropriate customers. Whether such customers are present within the country producing the HPSM, or whether they are abroad, will require that inspectors conduct routine checks on the loads of suspect trucks, ships or aircraft. And, such inspectors must be capable of quickly determining whether a material is, or is not, likely to be HPSM. Some simple tests can help. Hardness of non-magnetic material is usually related to strength, so that the measurement of the approximate hardness via a scratch tester or some other simple device could be a first screen.

   However, it may be that this requirement could be the subject of some innovative R&D, the object of which would be to design a direct recording device, capable of instantly reading out the hardness, approximate strength, elastic properties, surface chemical composition, presence of specific elements, and absorption spectrum via a surface contact probe. The development of such a device should be well within the capabilities of scientists at NIST and equivalent institutions in Russia, and might form an appropriate collaborative program.

   Other control suggestions and issues:

5. Documentation and Trends: The advent of increasingly smart computer networks provides the opportunity for increasing efficient detection of trend indicators that can provide clues as to production intent. The development of a central HPSM database and diagnostic program that can integrate information from a variety of inspection/control sources and signal when a critical path of capability is emerging would be a control tool well worth developing.
6. Laws and Penalties: Most advanced materials developments in the United States., Japan, and other countries are protected by patents, with legal opportunities for punishing persons who use the covered knowledge without permission. Russia must introduce such legal protection without delay if it is to expect foreign nations to transfer technology to it. Because the concept of private property still is not well established in Russia, it will be necessary to publicize extensively the issuance and significance of new intellectual property laws, and to develop severe punishments for breaking them. One suggestion that might enhance the effectiveness is that both the offender and his/her superior sustain appropriate punishment. This should catch management's attention.
7. Spin-On vs. Spin-Off of HPSM: During the past several decades, most HPSM were developed in response to specific military needs. However, with declining military R&D budgets in both Russia and the United States, HPSM will arise increasingly in response to specific commercial applications, and will only subsequently be applied to

military purposes. In the United States, such a situation is termed spin-on (to military use) as opposed to the traditional spin-off (from military to commercial applications).

Spin-on will be an increasingly likely event, especially for developments in the fields of electronics and photonics. However, since cost is a significant driver in the widespread use of structural materials (which explains the very limited advances which occurred in conventional aluminum alloys or cements over the past 50 years), it appears less likely that spin-on will be an important factor in HPSMs. In other words, HPSMs will continue to be produced principally for military purposes rather than for commercial purposes.

A Possible Transition Model for Hard to Soft HPSM Control

Many of today's complex commercial containing HPSM also have major content of non-strategic materials and related technologies. Joint ventures with the objective of marketing selected commercial systems on a global basis could be initiated within the parameters of the content of HPSM produced by COCOM nations. Remembering that HPSM are difficult to both produce and effectively incorporate into design, this initial approach would amount to relatively "hard" control.

As trust, the development of common values, and data relative to HPSM control are increased between the United States and Russia, hard control could progressively lessen. In parallel, Russia would have to demonstrate its willingness to control other nations' strategic and legal entities (assets) via the prevention of technology re-export, copyright laws, etc.

It is important to remember that the progressive disclosure of HPSM technology can increase the transfer of processing (manufacturing) technology and later incorporate the joint design of advanced systems. While such disclosure and cooperation may take a decade or more to evolve, joint activities could be initiated in a relatively short time frame.

RUSSIAN CONTRIBUTION FOR THE JOINT PAPER OF THE U.S. NATIONAL ACADEMY OF SCIENCES - RUSSIAN ACADEMY OF SCIENCES WORKING GROUP ON STRUCTURAL (FUNCTIONAL) MATERIALS*

Prof. Alexander A. Ovchinnikov
Corresponding Member
Russian Academy of Sciences
(Head of the Case Study for RAS)

INTRODUCTION

The following RAS prepared program recommendation is specific to organic materials. It should be noted that while focus was placed upon this domain, parallel Russian R&D capability encompasses the entire field of dual purpose HPSM listed in the American paper.

Materials science is a rapidly developing field of modern knowledge. The interest to fundamental studies in the field is mainly caused by immediate practical considerations. Both the development of high-tech branches of industry and the economic side of mass production depend basically on an accelerated introduction of new materials, optimized to the designed purpose. A new drive has arisen with an introduction of organic materials on a wider scale, and we are facing now an "era of polymers." Polymers and other organic materials have already made a noticeable impact on civilization, as they are used in many industrial fields as binders, glues, lacquers, insulators, synthetic fabrics, etc. A much stronger impact should be expected from the development and introduction of organic materials with designer properties—the so called "functional" or "structural" materials which are the subject of new branches of science, i.e., electronics of organic materials and molecular electronics. These branches of science have been brought to life by the demands of the defense industry and by the developments of high technologies. Research in these fields has consequently allowed the preparation of organic semiconductors, synthetic metals including superconductors, organic photo conductors, and organic and inorganic dielectrics including ferroelectrics. Organic materials with ferromagnetic properties have eluded materials science for a long

* Topic selected and approved at the 2nd U.S. National Academy of Sciences-Russian Academy of Sciences Joint Meeting on Dual-Use Technologies (Washington, May 1992) and presented at the 3rd U.S. National Academy of Sciences-Russian Academy of Sciences Joint Meeting on Dual-Use Technologies (Moscow, December 1992).

time. Nevertheless, this problem has now been solved both theoretically and experimentally.

The Russian school of materials science has played a recognized role in the development of this field, and the process of conversion now allows it to use its achievements for peaceful purposes and for universal development.

The structure of the Program is shown in the flow chart below:

PROGRAM STRUCTURE

Electronics of Organic Materials

Program Subgroups

Organic and Inorganic Ferromagnets	Polyfunctional polymers, conducting polymers, carbon containing materials	Second order nonlinear optical materials
Gas transducers based on organic semiconductors	Organosiloxanes binders and file forming materials	Theoretical investigations

The Program includes several subprograms from different branches of science, but all of them are aimed to solve most important problems in the field of electronics of organic materials.

Organic and Inorganic Ferromagnets

The design and synthesis of molecular magnetoresponsive materials (ferro-, ferri-, meta-, high spin para- and/or super-para-magnetics and spin glasses) is an area of steadily increasing interest among organic, inorganic, polymer, and physical chemists. Molecular magnets are desirable as they may have magnetic properties associated with light weight, solubility in organic solvents, and processability analogous to that of plastics and optical transparency, which could make them useful in the development of new electronic devices. They also provide an intellectual challenge to synthesize new classes of compounds that do not yet exist. Moreover, beyond the basic problem of establishing structure-property correlations, molecular-based magnetic materials appear promising for the development of totally new properties or associations of properties (in magnetooptics, as organic materials with nonlinear optical and magnetic response, or in studying organic conductors and superconductors).

Development of Highly Sensitive Photoresists Based On Polyfunctional Polymers

A possible line of development of the next generation integrated circuits leads to design and construction of molecular electronic devices. As device elements dimensions approach the submicron range, the introduction of new lithographic technologies are required. Resist layers with improved resolution and sensitivity are needed. In a new lithographic process, irradiation (visible light, ultraviolet, electron beam, X-rays, etc.) might not be used to obtain a pattern on a photoresist (with subsequent treatment of a plate through "windows" in a pattern) but rather for direct production of a working molecular device from polyfunctional polymers. The use of the photolithographic technique will allow one to obtain active organic elements having linear dimension smaller then l μ. The purpose is to create new highly sensitive resists based on polyfunctional polymers using both chemical and optical amplification.

Development of Polymer Compositions for Photochemical Etching of Metallic Films

The fabrication of metallic images finds a wide application in modem science and high technologies, particularly in manufacturing printed circuit boards, integrated circuits, optical disks and so on. For the fabrication of metallic images either many-stage lithographic processes or powerful pulses of excimer lasers (ablative optical recording) are needed. To achieve higher patterning speeds, an excimer laser irradiation of a copper foil, for example, is performed in Cl_2, Br_2 and halogenated methane atmospheres. Under irradiation gas-phase molecules or surface-bound adsorbates dissociate, giving halogen containing free radicals which rapidly react with metallic atoms in the film to produce the CuCl and CuBr surface layers.

The principal object is to develop a dry resistless process for the photochemical and electron-beam etching of thin metallic films by reactive fragments produced in a course of irradiation of the polymer layer cast on top of this metallic film.

Conjugated Polymers As Electroconducting and Electrochromic Materials

Conducting polymers are of great interest because of their unusual electronic properties as well as high conductivity and other features acquired with doping. The most important applications of the conducting polymers are connected with the modulation of their electronic and optical properties, ion diffusion rates, redox potentials, spatial dimensions, and so on. One of the most promising tasks is the investigation of composite materials based on conducting polymers and their applications in practice. The production of conducting polymer films of large area holds special interest for certain practical applications, such as smart windows, light filters, and heating panels. Thin conducting polymer layers will also be used as semitransparent electrodes in organic electroluminescent devices and photocells for the conversion of solar radiation.

Transport Properties of Conducting Polymers and Carbon-Containing Materials

Conducting polymers (i.e., polymers with conjugation in the main chain), and high temperature treated carbon containing materials are among the most promising classes of conducting materials. Extensive research in the domain of conducting polymers began in the early 1970s, after the synthesis of polyacetylene of a principally new structure and the discovery that its conductivity can be increased by over 10 orders of magnitude upon doping. Polyacetylene, possessing the simplest chemical structure $(CH)_x$, was studied using practically all physical and chemical techniques. The highest conductivity obtained on polyacetylene is as high as 10^6 $Ohm^{-1}cm^{-1}$.

In contrast to conducting polymers, carbon containing materials have been used for a long time. They are widely used in the aircraft and space industries for various purposes due to their superior mechanical and thermal properties. However, electrical properties of these materials are not yet effectively used, though they have conductivities as high as 10^4 Ohm^{-1} cm^{-1}. To this end, one should pursue primarily studies of transport properties together with structural investigations, and improve technology.

Carbon-containing materials are normally heat-treated in carbonization ovens for 15-20 hours or more. Recently, a new method of heat treatment (HT), just several seconds long, was proposed. Maximum conductivity obtained is_ 10^4 $Ohm^{-1}cm^{-1}$ for HT temperature of 1100°C. Electrophysical properties of these new films are practically unknown as yet.

Carbon fibers possess unique physical-chemical and mechanical properties that determine different fields of their practical application. Fibers of high modulus and strength attract particular attention. We propose to study fibers heat-treated in the laboratory and otherwise modified.

Carbon and Metallocarbon Clusters (Fullerenes)

The discovery of polyhedral carbon clusters is one of the most important events in chemistry of the last several years. It is the fourth allotropic modification of carbon (after diamond, graphite, and carbide) known to humans. The existence of Polyhedral carbon clusters was discovered experimentally in 1985 by observation of 720 (C_{60}) and 840 (C_{70}) masses in mass spectra of carbon vapors, evaporated by laser beam. The structure of both compounds was studied by different physico-chemical methods, including X-ray structure analysis. Now there are arguments of existence of a large family of such carbon clusters C_n, called fullerenes. Fullerenes provoke great interest due to their unique chemical and physical properties and to the prospect for creating new conductive, superconductive, magnetic, composite, and antifrictional materials, as well as biologically active and medical preparations. An arc evaporation of carbon is the main method of fullerenes production now. It involves forming soot, containing less than 15% of fullerenes (C_{60} (~80-85%), C_{70} (~15%-20%) mixture and higher fullerenes n>70(~1-2%)). However, the influence of synthesis parameters (current shape and form of graphite electrodes, gas medium, vacuum) on yield and structure of fullerenes is still not known in details.

Fullerene complexes are reported to show ferromagnetic properties, and Fluorinated fullerenes may exhibit lubricating properties. Thus, the first investigations of synthesis and properties of fullerenes show that these compounds are interesting both from a scientific point of view and as prospective sources of new types of useful materials. In particular, it can be predicted that fullerenes can be the basis of new,

- conductive, superconductive, and magnetic materials;
- materials and coatings, and thermostable and oxidation resistant materials
- materials for electronic applications.

Very recently, carbon nanotubes excited great interest. It seems that this new facet of carbon materials will be greatly stimulated by the discovery that pure nanotubes and nanoscale particles can be obtained with high yield.* These materials could find potential applications in areas such as catalysis, composite materials, nanowires and nanoelectronics. New experiments, which have shown that extraction yield of fullerenes can be increased considerably, are worth mentioning.

Photorefractive Crystals for Highly Sensitive High-Speed Optical Processing

Optical processing of information is now considered as very promising. New principles of computing architecture are based on parallel flow and processing. Photorefractive crystals may be used in such an architecture as interconnectors, integrated neural network processors, and memory elements. To perform these functions, high resolution dynamic holograms should be recorded in the media. The necessary sensitivity, processing speed, and resolution may be achieved only as a result of joint work on crystal growth technology and determination of nonlinear optical properties. Special demands for the crystal arise in applications to phase-conjugate lithography and tracking systems for optical communication.

It is planned to investigate the crystals barium, barium titanate, strontium barium niobate, lithium niobate, barium titanate, potassium niobate, GaAs, InP, and some other new materials, with the aim of control of the growth conditions. The methods of investigation are two- and four-wave mixing in the presence of DC and AC externally

* Ebbesen, T.W., and P.M. Ajayan, Nature, vol. 358, July 16, 1992, pp. 220-222.

applied fields, including phase-locked detection of a running interference pattern and self-organization processes in the light/nonlinear crystal system. The result of the optical part of those studies will consist of the recommendations for types and concentrations of necessary dopants as well as aftergrowth handling technology.

Nonlinear Optical Materials for Second Harmonic Generation (SHG)

Semiconductor lasers and diode-pumped solid-state lasers presently demonstrate high efficiency, compact size, and moderate cost. However, they radiate in the near infrared (IR) region of spectrum, whereas many commercial applications use visible light.

A solution of the problem is the frequency doubling of light. However, for most strongly needed low power quasi-CW devices, the doubling efficiency via known materials and schemes proves to be low. The objective of this part of the subproject is to develop the growth technology for the known KTP and KDP crystals with much better quality and to study the new alternative methods of SHG. The latter include the integrated optical approach and the record of second order nonlinearity gratings in amorphous materials.

Gas Transducers Based on Organic Semiconductors

The demand for sensors for determining the composition of gaseous and liquid mixtures is constantly increasing and stimulates the search for new, particularly organic materials for the transducing sensitive elements (TSE). Environmental protection requires a determination of pollution sources, mechanisms of action, gradient, and temporal changes profile as the major problems of local monitoring. From the ecological point of view, the most dangerous pollutants are gaseous oxides and volatile hydrides that are formed as a result of human activity, as well as gases, having limited occurrence but higher toxicity that are used in a number of technologies. These include AsH_3, PH_3, and some volatile inorganic compounds containing Bi, Tl, Pb, Hg, and others used in special processes. For the solution of the above problems, one needs inexpensive, low energy sensors of sufficient sensitivity and selectivity, with preference given to the ones of the directed appointment rather than gas analyzers.

It is necessary to state from the very beginning that there is no civilian mass production of instruments for gas analysis based on organic materials, either in Russia or overseas, though the studies and design project in this direction are being intensively carded out.

Virtually all classes of organic substances are present among the materials, which are used in TSE polymers and low molecular organic and inorganicorganic compounds, dyes, charge transfer complexes and ion-radical salts, biological substances and free-radicals, and also their various compositions and modified materials.

The use of a simple resistive variance of a gas sensor may not fully satisfy the sensitivity of the requirements. These parameters may be reached by the conjugation of the properties of an organic material with traditional n-p-junction in Ge, Si, or GaAs. The various modes are possible with the use of high level fundamental studies in organic materials science and the studied properties of organic substances variable with a gas impact.

There is unique information on NH_3 detection with a piezocrystal, an L2-glutaminic acid at a thousand-time excess of CO NO_2, HCl, H_2S, SO_2, CO_2.

Sensors of NH_3, AsH_3, NO_x based on Pb-substituted phthalocyanines derivatives of quinoline and acridine, a number of donor and acceptor polymers (polyvinyl and siloxane based) should be noted among the works of Russian authors.

The reason for the limited application by industry of sensors based on organic materials is insufficient insight into their fundamental electrophysical, structural and technological properties, into mechanisms of gas interaction with their surfaces, and interface phenomena in MDS-structures. If one considers the total expenditures for the design of such sensors, it turns out that they are incomparably less than the ones which have been allotted for a design of sensors based on inorganic compounds, particularly, transition metal oxides.

Accumulated scientific experience allows one to assume very good perspectives for advancing gas sensors based on organic materials, which should be economical and energy conserving.

Organosiloxanes Binders and Film-Forming Materials

Organic binders and film-forming materials have been known for centuries and have been exhaustively studied during the last 30 years. The volume of their use nowadays has probably reached its limit. An obstacle for further expansion of their use is inherent in their chemical nature. Virtually all of them are flammable, water-sorbing, weather-sensitive, dangerous (poisonous fumes) on oxidative decomposition, and/or unstable at elevated and/or low temperatures, under UV-irradiation, etc. New opportunities may arise as a result of R&D studies and application of inorganic, especially siloxiorganic polymers.

Theoretical Investigation of the Characteristics of a Charge: Carrier Transport in Polymer Matrices

In recent years a significant effort has been expended to understand the main features of the charge carrier transport in the disordered organic matrices, such as various polymers or the low-molecular-weight organic glasses. This effort was stimulated both by the pure scientific interest in the characteristics of the highly disordered materials and by the commercial uses of such transport processes in copiers and laser printers, for instance.

A Study on Multicomponent Functional Optical Ceramics Based on Metal Fluorides

The study goal lies in vastly increasing the assortment and application of inorganic fluoride materials in modem fields of science and technology, improving exploitation performances, and lowering production costs. Objectives can be achieved by substituting the traditionally used single-crystalline materials for their polycrystalline form (optical, ceramic-OC), simultaneously using multicomponent compositions instead of a single component.

Multicomponent functional optical ceramics (MFOC) are prepared by a hot pressing technique. Up to the present, articles produced by this technology have found application primarily in military fields. The study provides improvements in hot pressing technique to prepare new fluoride MFOC with a specific (partially disordered) structure and properties available in wide limits for civilian purposes.

The study provides new information on the chemistry and physics of solids with high concentrations of structural defects (with strongly distorted stoichiometry).

Behavior of MFOC as polycrystalline material is complicated by high concentration of one-and two-dimensional defects in a real structure (dislocations, grain boundaries), the contribution of which in exploitation performances will be the object of the investigation.

The practical importance of the study is the preparation of fluoride MFOC surpassing single-crystalline analogs by technico-economical characteristics.

The largest-scale peaceful applications of the fluoride MFOC, which have been established for the single-crystal analogs are:

- new generation of scintillators for application in high energy physics, nuclear physics, astrophysics, nuclear medicine, and related fields, which have high time resolution, high density, radiation hardness, low cost, and other improved characteristics;
- optical construction materials (lenses, prisms, etc.) for scientific instruments, air-space technology, and other uses; and

- chemical sensors for fluorine in gaseous atmospheres for automated and controlled metallurgical and chemical production processes, as well as for monitoring the environment.

HIGH-PRECISION WEAPONS AS A PHENOMENON OF THE TWENTY-FIRST CENTURY

General Oleg K. Rogozin (retired)
Principal Research Scientist, RAS Elorma Program
Former Deputy Chief of Procurement, Soviet Ministry of Defense

The constructive discussion on the dangers of a spontaneous and uncontrolled dissemination of "dual-use" technologies under the conditions of conversion both confirmed our mutual understanding of the importance of this problem and compelled both sides to search for radical ways of solving it.

Indeed, the fact that the world, and especially the West, has become highly explosive and vulnerable to the power of not only nuclear weapons but also conventional high-precision weapons is becoming more and more obvious to specialists and clear-thinking politicians. The possession of such weapons equalizes the military-strategic and geopolitical chances of opposing countries (coalitions), despite considerably different levels of economic, scientific, technological, and military development. Any preventive (preemptive) strike using conventional long-range weapons against key targets in an economically highly-developed country can at once transform its territory, as well as the territories of the neighboring countries, into absolute ecological hell! It is sufficient to remember the self-destruction of just one nuclear block of the Chernobyl nuclear power station. And in Western Europe alone there are more than 90 nuclear power stations.

This possibility should be taken as an axiom and we should proceed from this premise when dealing with our own most important military-strategic problems and those of international security. The probability of such a scenario is being transformed from a theoretical possibility into an urgent and serious problem.

Today, not only Russia is sick, but also many other countries are sick politically, economically, and socially. Among them are countries overloaded with weapons, such as the former Soviet republics and many former members of the Warsaw Treaty Organization. The fires of war in Yugoslavia are not dying out. The ideas of Islamic fundamentalism are becoming more attractive to peoples in the republics of Central Asia, including Kazakhstan, which possesses nuclear weapons. The southern borders of Russia and Ukraine are practically invisible. Negative tendencies toward considerable and sharp changes in the postwar world order will increase in the near future. The particular danger lies in the political, economic, and social instability in Russia, which for the time being is the main factor and guarantor of geostrategic stability in the Eurasian region. Russia and Ukraine are still having a territorial dispute over the Crimean peninsula, and the fires of military conflicts are still raging in Karabakh, Georgia, Ossetia, and Tadjikhistan. The situation in Moldova remains highly explosive. All of this leads to a situation where the real (not theoretical) thrust of a military threat is changing from "East-West" to "North

South", while of all the great powers, Russia, with her clearly weakened military potential, finds herself in the worst situation.

All this gives serious incentives to politicians and Western and Eastern peace-loving establishments to search for new fundamental military-strategic approaches, as well as for nontraditional philosophical and political assessments of how to protect civilization from ill-intentioned or accidentally provoked regional and global catastrophes.

From the complete range of military-strategic problems directly linked to the conversion of "dual-use" technologies, the key problem, in our opinion, is the issue of nonproliferation (containment) of long-range (>300 km) high-precision weapons. However, we should mainly consider questions within the areas of competence and responsibility of our Academies of Science: specifically, how to prevent the results of fundamental and applied research, which could assist in the creation of more powerful high-precision weapons, from falling into the wrong hands during conversion. You can see that while the world community has worked diligently and with some success on curtailing the proliferation of weapons of mass destruction, just one agreement (in which the former USSR does not participate) is directed toward limiting the proliferation of conventional weaponry manufacturing technologies. It shows that the world community has not yet clearly realized this growing phenomenon of the twenty-first century, which is not less menacing than weapons of mass destruction! Maybe we will turn out to be the first "worded scientists," capable of persuasively informing the world community about this new global danger.

The delivery system is an important component of any type of weapon. Unfortunately, all conventional and possible future delivery systems of weapons of mass destruction can also be used to deliver high-precision munitions, which complicates the problem of identifying and differentiating between high-precision weapons and weapons of mass destruction. In addition, while the existing weapons of mass destruction and their parameters (number of blocs, geographical locations, capabilities of use, et al.) are well-known and defined by agreements between the members of the "nuclear club," there is practically no international quantitative and qualitative curtailing of high-precision weapons. High-precision weapons also are highly mobile, have incomparably wider range of types and nomenclature than weapons of mass destruction, and they can be used both as an aggressive weapon (in the hands of an aggressor) and as a defensive weapon (in the hands of a peaceful nation). And, finally, the high technical complexity of high-precision weapons attracts practically every conceivable scientific endeavor, among which we give the priority to optical electronics, information science, and computer engineering, as well as engineering of new materials and substances.

As mentioned above, the area of responsibility of our National Academies are the forms of collaboration, represented in the first and partially in the second blocks (bottom line), i.e., fundamental and applied research. As we see, there is a great diversity in the types of scientific and technical collaboration, which complicates verification of converted scientific "product" and, consequently, the export control over its transference abroad. General Igor Lebedev will report on current export controls of the Russian Academy of Sciences, so I do not need to expound on them here. However, I would like to express what is a very important consideration, in my opinion. Neither export controls during conversion, nor free "brain" travel (or more precisely-their carriers, the young, capable Russian scientists living on the verge of poverty) could make people forget the subject of their scientific work and prevent an unintentional transfer of it to a dangerous client! I suppose that most U.S. scientists and experts agree with this, among them the CIA director Robert Gates, the House of Representatives Armed Services Committee vice-chairman Charles Bennett, the president of the Rensselaer Polytechnic University professor Roland Schmitt, and others.

In conclusion, I would like to suggest several proposals.

First, all progressive scientists, especially American and Russian scientists, should direct the attention of the world community toward the necessity of creating strict and comprehensive means of control over proliferation of strategically dangerous weapon systems, "dual-use" (convertible) technologies that can be used to develop new high-precision and, most importantly, long-range weapons. Particular attention must be paid to eliminating the possible transfer of high-precision weapons and corresponding "dual-use" technologies to potentially dangerous countries of the Third World, such as countries dominated by Islamic fundamentalism, which aspire to establish a new world order.

Second, all progressive scientists should strive for the creation of mechanisms of international control over the possible development of "flash points" on our planet, where completely unjustifiable concentrations of high-precision weapons for various areas of application (on land, in the air, in the ocean, and in space) exist, and for taking political, economic and other measures for blocking of these concentrations in a timely manner.

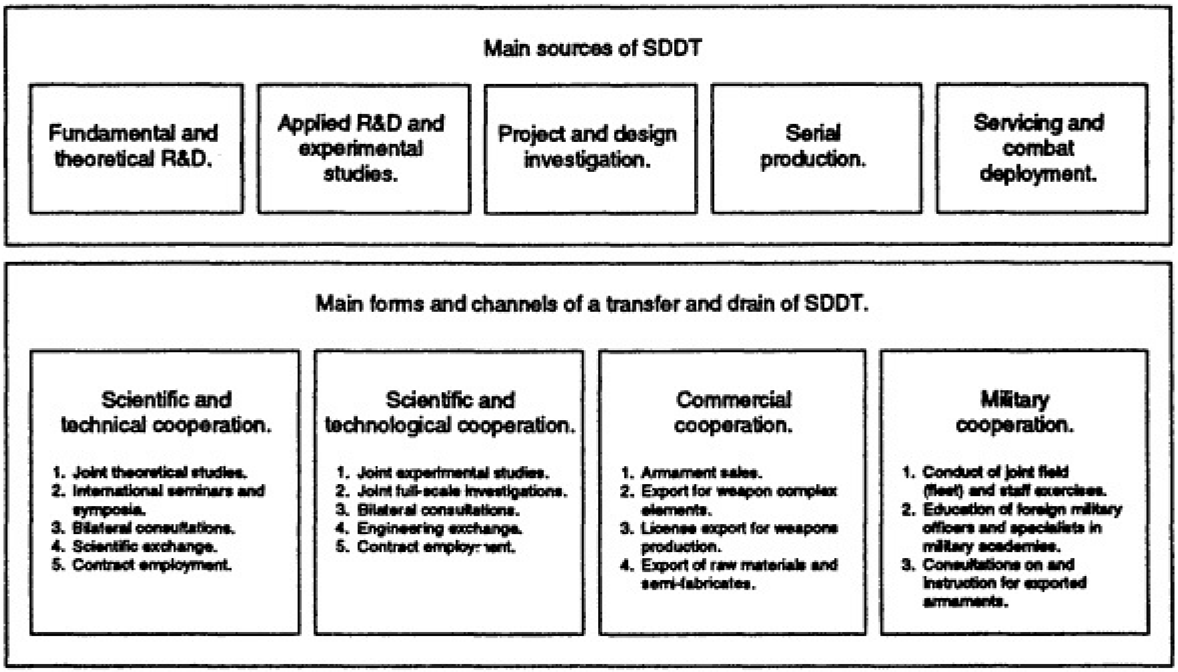
Third, all progressive scientists should direct the attention of the world community toward the necessity of developing principles and criteria for evaluating the development of armed forces and armaments with a purely defensive structure and composition, and reliable and distinctive external indications of defensive weapons, which, along with on-site inspections, will increase mutual trust, eliminate unjustifiable menacing actions by peaceful countries and will assure timely discovery of any preparations for war or aggression.

Fourth, all progressive scientists should direct the attention of the world community to the necessity of developing an international system under the aegis of the United Nations for the effective control of space and the atmosphere, that would prevent the unsanctioned and provocative use of high-precision weapons and intercept and neutralize them in flight.

Fifth, all progressive scientists should direct the attention of authorities toward the necessity of material and moral support of scientists whose work is related to the development of technologies of weapons of mass destruction, primarily of high-precision long-range weapons. Special attention should be paid to provide an urgent support of scientists and specialists of member countries of CIS (Russia, Ukraine, Belarus, and Kazakhstan), since these countries possess strategic nuclear weapon delivery systems.

Sixth, American and Russian scientists, as well as scientists of other western countries that produce and export weapons, should create a data bank on critical parameters of high-precision weapons, and an international data bank of strategic and military-technical concepts, definitions and terminology. These data banks would help to eliminate exports of dangerous weapons to the countries of the Third World, as well as to reduce the semantic incompatibility during international negotiations and procedures on military-technical matters.

Thank you for your attention. I am far from the thought that I have covered all possible aspects of such complicated problem. I suppose my colleagues professor V. Tsymbal and A. Danilevich, as well as our colleagues from the U.S. National Academy of Sciences, will contribute their ideas to this.



OBJECTS OF BILATERAL EXPORT CONTROL FOR NON-PROLIFERATION OF STRATEGICALLY DANGEROUS DUAL USE TECHNOLOGIES (SDDT)

International Agreements / Participant States	USA	Russia	France	Germany	Canada	UK	Italy	Spain	Japan	Portugal	Greece	Belgium	Australia	Denmark	Ireland	Luxembourg	Holland	Norway	Switzerland	New Zealand
1. The Non-Proliferation Treaty Exporters Committee, 1984.	•	•	•	•	•	•	•													
2. The Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (biological) and Toxin Weapons and on Their Destruction, 1972.	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
3. The Missile Technology Control Regime, 1987.	•		•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
4. Treaty on Conventional Armed Forces in Europe, 1990.		NATO countries-WPO countries (23 states)																		
5. Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles, 1987.	•	•																		
6. Treaty for the Prohibition of Nuclear Weapons in Latin America, 1967.		Countries of Latin America (25 states)																		
7. Treaty on Non-Proliferation of Nuclear Weapons, 1970		141 countries, including RSA, Pakistan, India, Israel																		
8. Agreement on Measures to Reduce the Outbreak of Nuclear War Between the USA and the USSR, 1971.	•	•																		
9. Treaty on the Prohibition of the Emplacement of Nuclear Weapons and Other Weapons of Mass Destruction on the Seabed and the Ocean Floor and in the Subsoil Thereof, 1971.		102 countries																		
10. South Pacific Nuclear Free Zone Treaty, 1985.																				
11. Strategic Arms Reduction Treaty, 1991.	•	•																		
12. Strategic Arms Reduction Treaty, II, 1992.	•	•																		

PARTICIPATING STATES IN INTERNATIONAL AGREEMENTS ON CONTROL OF WEAPONS OF MASS DESTRUCTION

Nuclear weapons and means of their delivery.	Chemical weapons and means of their delivery.	Biologic weapons and means of their delivery.	High precision long range (300 km) conventional weapons and means of their delivery.

MAIN TYPES OF SRATEGICALLY DANGEROUS ARMAMENTS (SOA)

Land and sea based intercontinental and tactical ballistic missiles.	Aviational and sea based strategic and tactical winged missiles.	Space and aerospace carriers.	Aviational passive and aeroballistic carriers.	Carriers of advanced tactical systems of massive firing.	Aviational and sea based carriers with advanced tactical armaments (planes, submarines,ships.]

Main means of delivery of SDA (carriers)

Noise protected control systems and optical systems for high precision armaments (radar, heatvision, combined).	Powerful munitions and high energy fuels.	Micro-electronics and supercomputers utilizing new elements for weapon control systems.	Materials and substances for diminishing the radar and heat detectability of armaments.	Low noise mechanisms for submarines and surface ships.	Materials and substances with basicaly new properties, especially organic materials.

The most important elements and materials for SDA

HIGH-PRECISION WEAPONS

Colonel V. Tsymbal (reserves)
Professor, Russian-American University
Co-Director of the RAS Elorma Program

While elaborating on the ideas mentioned in the report of Professor O. Rogozin, I would like to emphasize again that high-precision weapons are today becoming the main means of realizing a deterrence strategy. The threat of retaliation using high-precision weapons against an aggressor is completely different from the threat of retaliation using weapons of mass destruction.

I would say that high-precision weapons allow highly accurate and measured retaliation, to strike not only at the appropriate place (for example, against the main arsenals or against the rulers of an aggressor state) but also using the most rational means, by varying the trajectory, time and direction of the strike, the type and characteristics of the munitions selected. These are fragmentation-demolition, volume-detonating, and incendiary munitions, or even electromagnetic wave weapons that would destroy only electronics. However, as General Oleg K. Rogozin properly noted, even those weapons can become exceedingly dangerous if they fall in the hands of men with evil intent.

From a technical point of view, high-precision weapons, or guided weapon systems, contain elements used in many technical systems, especially those in civil aviation. These systems include compact sensors and basic navigation tools—the inertial control systems. Equipment for receiving signals from satellite radio navigation systems is also used. It is very difficult today to find an aircraft or an ocean liner without similar equipment. Even automobiles are becoming equipped with navigation devices. Guided weapon systems use highly-efficient engines, advanced construction materials, and other inventions. State-of-the-art computers and algorithms (software) are used to run many subsystems, to develop devices of automatic situation analysis, to make "rational decisions". American and Russian cruise missiles ALKM and "Tomahawk", anti-ship missiles, and other guided weapon systems are well-known examples of high-precision weapons.

All elements of high-precision weapons, even combat munitions, may have dual-use. Then, what is the difference between nondangerous and potentially dangerous elements and technologies? The difference lies not only in their functions, but more importantly in their parameters (quantitative characteristics) which, together with the introduction of corresponding subsystems, permit the creation of highly effective high- precision weapons. For example, if a navigation error of a device is measured by a few meters, there is no doubt it exceeds industrial requirements and may be used for navigating high-precision weapons.

It follows then that while considering new scientific and technical achievements from the standpoint of their undesirable use by potential aggressors for the purpose of creating high-precision weapons, a coordinated evaluation of the threshold significance of the main scientific and technical parameters is needed. It is time to begin this work at the international level, to compare the methods and initial data possessed by the specialists of our countries, and to coordinate the results of these evaluations. This can also be tied to the process of deciding which weapons to sell to the Third World countries.

However, I do not think it is possible to stop completely the spread of technologies that can be used for developing high-precision weapons. There are too many areas of their application and they are just too valuable to economic growth.

Therefore, countries concerned about international security should start working ahead of time on the creation of technical means and application methods that would allow them to neutralize the high-precision weapons of aggressors or at least sharply diminish the weapons' effectiveness. Without going into detail about what the United States did in destroying Iraqi air defenses, which were armed with high-precision antiaircraft guided missiles, we should point out the very fact of the successful resolution of this problem.

Therefore, if highly developed peaceful countries are successful in creating technical means capable of neutralizing high-precision weapons of potential aggressors, the necessity of including components of these high-precision weapons and related technologies on restricted lists will become less critical. After all, in the final analysis we are interested in the widespread use of useful technologies.

These facts lead to one more area of collaboration between American and Russian specialists. The various types of research that I mentioned are probably as important as the development of new technologies. Therefore, I propose to note this area of collaboration in the final document and to provide material support for it.

THESIS OF A SPEECH ON DUAL-USE TECHNOLOGIES AND EXPORT CONTROL

General I.P. Lebedev (reserves)
Scientific Secretary, RAS Council on Export Control

Very good and strong arguments, as contained in the opening remarks of the chair of the Russian Academy of Sciences delegation, Academician Gennadiy Mesyats, and in the reports of Doctor of Technical Sciences, O.K. Rogozin, Candidate of Military Sciences Danilevich, and Professor V.I. Tsymbal, show the importance of the discussions of the problems of dual-use technologies between the Russian Academy of Sciences and the American National Academy of Sciences.

Major changes in Russian legislation permit us to conclude that both the Russian and American Academies use the same principles when dealing with problems of exporting results of fundamental research and applied research. The Russian President's Decree # 308 on the Creation of an Export Control System in the Russian Federation (abbreviated as "Russian Export Control"), issued on April 11, 1992 and published in our press, can serve as an example of this. The Russian Academy of Sciences is a part of the same system.

The Council for Export Control of the Russian Academy of Sciences was established on June 28, 1992, by Resolution #209 of the Presidium of the Russian Academy of Sciences, and Academician G.A. Mesyats (vice-president of Russian Academy of Sciences) was nominated as president of this Council. Five academicians, nine corresponding members, lawyers, economists, and financial specialists are members of the Council for Export Control. We are certain that such a competent and, more importantly, highly scientific staff of the Council for Export Control can execute the export control of dual-use technologies in a highly qualified manner.

The Russian Academy of Sciences, within the limits of its authority and the limits of Russian legislation, has as its goal during our present negotiations the development of specific recommendations for examination and decision making of government authorities regarding the main directions of specific fundamental and applied research in the area of dual-use technology.

We have prepared three lists of restricted items, which we would like you to examine and then submit your suggestions. Of course, it is impossible to do this immediately, but we do ask your favor to do so by the next conference. These three lists have been introduced into practice in the Russian Academy of Sciences, and our scientists follow them when dealing with export matters. The lists of restricted items are, naturally, open, i.e., they are not classified and they have been published in our press. The lists of restricted items of the American delegation (the Department of Commerce list) will be examined by the Russian Academy of Sciences and will be submitted with our comments for further consideration to appropriate Russian governmental authorities.

The American delegation asked many questions on subjects that are within the competence of the government of the Russian Federation. We must inform you that in order to receive answers to these questions, you should address them to established channels in the Russian Embassy in Washington, D.C., and we are certain that answers will be given at the corresponding level. The Russian Academy of Sciences will provide to our governmental organizations scientific consultations related to specific subjects of fundamental and applied research.

Mutual trust between the scientists and scientific organizations of our Academies is the basis of collaboration on the problem of fundamental and applied research in the area of dual-use technologies. We know very well that Americans are pragmatists and require not only words, but also practical confirmation or, as you say, guaranties and a system of sanctions for violators.

Let us recall the trust that used to exist between our countries during the Second World War (the speech on extending lend-lease to our country that President Roosevelt gave to the American Congress and Russia's collaboration with the Bell Company—its scientific laboratories, engineers, and specialists—in eliminating defects of the aircraft "Aircobra"); they did not believe our words, they required proof. In the case of our work with Bell Company, our test pilots and military representatives proved in practice the presence of defects (e.g., the aircraft developed a "flat spin" under certain conditions) when an airplane piloted by a Russian crashed before the eyes of company representatives. Company specialists and scientists then redesigned the aircraft and eliminated the defect, thus preventing the deaths of other pilots. That was a period of mutual trust and friendship.

Today, we should renew this trust and mutually protect dual-use applications from the possible unsanctioned use for creation of weapons, especially of weapons of mass destruction. In that respect, both of our export control systems should work effectively without restraining scientific progress, without impeding economic development of our countries, providing mutual support for scientists to eliminate "brain drain", which both delegations have discussed.

Concerning a system of sanctions for violations of the established export control regime, you do not have to worry about us. We know that the American legislation stipulates ten years of imprisonment for violations, and Russian legislation stipulates 15 years of imprisonment.

All other guaranties will be stipulated in agreements on grants and scientific collaboration, and any changes will be coordinated between both sides. Meanwhile, as

Academician G.A. Mesyats stated, we consider your grants to represent the voluntary, special scientific charity of American funds and other nonprofit organizations.

CONCEPTUAL APPROACHES TO THE PROBLEM OF DUAL-USE TECHNOLOGY

Mitchel B. Wallerstein, Ph.D.
Deputy Executive Officer, National Research Council

During the past twenty years, there has been a significant reversal of the post-WWII model for military technology development. Since the early 1970s, a growing fraction of the new technology required for the next generation of military systems has been derived from or closely related to commercial (i.e., civilian) development efforts, rather than programs strictly and separately supported by the military. Moreover, following the philosophy of "spin on", largely pioneered by the Japanese, companies in the West are now actively looking for opportunities to apply commercially-developed technology to military systems, rather than the other way around, as in earlier days.

These changed conditions of technology development, combined with the rapidly growing and extremely widespread availability of many previously-controlled items such as personal computers, semiconductor chips, etc., makes it extremely difficult, if not impossible in some cases, to continue to enforce comprehensive restrictions on the export of sensitive dual-use technologies.

At the same time, it must be recognized that the export of these dual-use technologies is likely to be extremely important to the future health of the Russian economy. Thus, the lack of participation by republics of the former Soviet Union (FSU) in the international system of export controls will represent a serious obstacle to their economic recovery.

There are two continuing concerns. One relates to the continuing political, economic, and social upheavals in the FSU and the uncertainty about its future course. The other pertains to the possibility that states of the FSU may, for understandable economic reasons, become the source of export for many dual-use technologies to third countries seeking the means to produce or acquire weapons of mass destruction. Both of these concerns remain very real today in the United States and other Western countries, and they continue to figure prominently in the approach which these nations have taken towards assisting in the conversion of defense industries in FSU.

It is worth noting, in this regard, that we are collectively facing what is sometimes referred to as a "chicken or the egg" problem. In other words, it is not evident, at least not to policymakers in the West, which can or should come first: demonstrable evidence of the conversion of some significant fraction of the FSU defense industry to the production of civilian goods, or expanded access to advanced technology and capital needed to spur that conversion. One of the principal objectives of the NAS-RAS project is, of course, to identify and promote specific confidence-building measures that will permit technology transfer and capital investment with greater certainty that the new capabilities enabled will not in fact find their way into military systems or be incorporated into items for export to countries of proliferation concern.

Finally, it is worth pointing out that change, if it is to come and if it is to be meaningful, will require new modes of behavior and intellectual approaches on the part of all parties. To be frank, there continue to be residual concerns in the U.S. and NATO military establishments that near-complete elimination of controls on technology exports to the FSU could look reckless and foolhardy, in retrospect, if there were to be serious political reversals in the Russian Federation and a resulting change of leadership and foreign policy. By the same token, the question must be asked whether the Russian national security establishment has yet fully accepted the idea that on-site verification of converted military-industrial enterprises—similar to the kind of verification agreed to in the terms of the INF, START I and START II agreements—will be necessary to promote greater confidence in the West. It is also unclear whether the Russian military is fully engaged in the process of formulating Russian controls on indigenously produced technologies and end products.

Moreover, in recent site visits in Moscow, St. Petersburg, and Perm, it was indicated that some military-industrial enterprises that are in the process of converting are being required to retain their military manufacturing production capacity, or at least the capacity to reconvert to military production on a rapid basis in the event of an external threat. While every sovereign state must obviously have the capacity to mobilize its manufacturing resources in defense of the nation, it must be recognized that, for the next few years at least, any such reconversion involving dual-use technology acquired in the West would appear threatening to the COCOM countries.

There are, at the same time, a number of hopeful signs that the situation is improving. Among the most important of these developments is the recent decree by President Boris Yeltsin that formally established an export control policy for sensitive dual-use technology. A second is the creation of an Export Control Council in conjunction with the Russian government, with major participation by representatives of the Russian Academy of Sciences. There also has been a series of potentially important proposals discussed within the context of the new COCOM Cooperation Forum in Paris.

Before describing and commenting upon what has been proposed there, let me note that the licensing of sensitive dual-use exports to the FSU in the United States has already improved substantially. Just prior to coming to Moscow, I obtained from the U.S. Commerce Department the latest data on licensing case submissions to COCOM for the period from January 1991 through October 1992. As you may know, only the most sensitive cases must be referred to COCOM in Paris for multilateral review; the remainder are decided by national authorities on the basis of "national discretion."

The data reveal that, during this nearly two-year period, there has been a significant increase both in the number of licenses sought—meaning that export of a larger volume of sensitive technology to the FSU is being pursued—as well as in the number of approvals granted. Indeed, the absolute number of so-called "favorable consideration" decisions is up nearly 300%, and the rate of overall approvals nearly doubled during this period. Perhaps more significantly, the number of license denials is now approaching zero; for the period from January-September 1991 there were a total of 4 COCOM case denials, while for the period of October 1991 to October 1992 there were only 2 licenses disapproved by COCOM.

Now, it is certainly true that these raw numbers do not reveal that Western companies still do not attempt to obtain licenses for certain highly sensitive technologies above a specified performance thresholds. But the clear implication of the data is that the United States and other Western countries are already moving strongly in the direction of a policy of so-called "favorable consideration"—i.e., a presumption of approval—for all reasonable technology exports to the Russian Federation, the other states of the FSU, and other former member states of the Warsaw Treaty Organization. It is therefore no longer accurate to claim, in most cases, that technology is being withheld where civilian end use can be clearly demonstrated.

This sets the stage for the historic, first meeting of the COCOM Cooperation Forum (CCF) in Paris. The CCF was agreed to by the seventeen member states of COCOM in late 1991 in recognition of the fact that the Cold War had ended and that fundamentally new security threats, related to the proliferation of weapons of mass destruction, now exist that are shared in common by a large group of nations, including many that were former adversaries. Forty-two nations, including all but three of the republics of the FSU, attended the first CCF meeting in November 1992. The objective of the Forum was to establish common ground between like-minded nations on the need to control the proliferation of weapons of mass destruction and, in the process, to develop modalities for accelerating the further reduction—and near elimination—of remaining controls on sensitive technology moving from the NATO countries, Japan, and Australia to the former Warsaw Treaty states.

From reports I have received from those who attended on behalf of the United States, the meeting met or exceeded expectations. The Russian delegation was headed by Deputy Foreign Minister Grigory Berdennikov, who also held bilateral discussions with the United States while in Paris. The nations attending apparently agreed to cooperate more closely on measures to control the export from their territory of sensitive technology and end products to countries of proliferation concern. The delegations also discussed specific measures, which, if agreed to and implemented, would result in further relaxation and near elimination of the old West-East COCOM controls. The following proposals are now under consideration by the government of the Russian Federation and certain other nations attending:

- Demonstrate at the national level a strong, continuing political commitment to ensure the civilian use of sensitive technology in the domestic context and to regulate effectively the export of technology to other countries.
- Agree to permit pre-license checks of proposed importers to establish their *bona fides* and their capacity actually to use the items they are proposing to purchase. In addition, agree to permit post-shipment verification that the item in question is in place and is being used for the purposes described. These procedures would be supported by the so-called IC/DV procedure, which are pre- and post-licensing certifications routinely provided by the government of the importing country.
- Agree to establish a set of policies and procedures, and competent bureaucracy to process licenses, for the export of sensitive technology from the country. In most cases, this will require either the creation of new mechanisms or the substantial upgrading of existing structures and policies.
- In parallel with the above, agree to upgrade massively border controls and the capability of Customs authorities to enforce controls. (This particular problem relates to the so-called "weakest link" dilemma, wherein unscrupulous traders would attempt to seek out the state with the weakest border controls and enforcement mechanisms through which to sell items or technology to countries of proliferation concern.)

The U.S. has offered up to $11 million in Nunn-Lugar funds to facilitate implementation of these proposals. Most of this money would go to the Russian Federation and to the other three republics of the FSU that produce or possess nuclear weapons and advanced dual-use technologies that contribute to weapons of mass destruction. In addition, the United States has offered to conduct workshops and tutorials, both in these countries and in the United States, to explain how to set up the necessary licensing procedures, and so on.

This is similar to the activities that the U.S. government has undertaken in Hungary, Poland, and the former Czechoslovakia, with the result that licensing requirements for them have been relaxed and are in the process of being eliminated. These three countries are therefore held up as models. Hungary has already accomplished full decontrol by COCOM, and Poland and the former Czechoslovakia are near to achieving the same status. All three have established control measures and bureaucratic structures, and Hungary in particular has satisfied COCOM governments that it is now willing and able to undertake licensing and enforcement and to act responsibly with regard to the export of indigenously produced technology and end products.

Although not an explicit *quid pro quo*, there is an implicit understanding that, if the proposals tabled at the CCF are implemented by the NIS republics and other former WTO states, the COCOM countries would, as a first step, move immediately to a status of full "favorable consideration" of licenses, as soon as each of the CCF cooperating states signs a letter of commitment. Once the measures are actually implemented, the next stage would be to move progressively to so-called "national discretion" licensing, wherein the government in question would be trusted to regulate most items on its own, with a very small so-called "general exceptions" list remaining that would still require approval of the exporting state. This is, essentially, the current situation with regard to Hungary, and will soon be the case for Poland, the Czech Republic, and Slovakia.

The other major implication of the CCF discussions is an understanding that each of the participating nations is willing to be "a good global citizen" regarding its participation in the various proliferation control regimes.* Much remains to be done to bring the Russian Federation and the other three nuclear NIS republics in full compliance with these regimes, particularly the dual-use aspects of the Nuclear Suppliers Group and the MTCR. The FSU was a cooperating participant with—but not a member of—the MTCR, and the Russian Federation has asked for formal admission. At the same time, however, there have been recent problems, including for example, the U.S. sanctions imposed on Glavcosmos in the wake of its sale of cryogenic liquid rocket engines to India.

Let me return, finally, to the "chicken or the egg" problem referred to above. There are probably at least two dimensions to this. First, the conversion of military-industrial enterprises in Russia and the other NIS republics obviously must continue and, to the extent that the severe economic constraints can be overcome, should be accelerated. This must be accompanied by a policy of openness and transparency that would include agreement to permit various types of inspections—possibly by third parties or under the auspices of the United Nations—to increase confidence that sensitive technologies and specialized end products are not being used in the production of military systems. (It is to be hoped that the recommendations agreed to as a product of the joint NAS-RAS expert committee will be helpful in this regard.)

Second, there should be demonstrable evidence that the Russian military and defense establishment is supportive of and involved in controlling munitions and sensitive dual technologies, both with respect to their internal use within the FSU and their export to third countries. At the same time, the United States and the other COCOM countries must work to speed up the favorable consideration of licenses and help in other direct and indirect ways to facilitate defense conversion and economic development in the FSU. These steps, together with the bureaucratic measures outlined earlier, should create the possibility of a substantial further reduction, if not the virtual elimination, of the

* These regimes include the Nuclear Non-Proliferation Treaty, the London Suppliers' Group, the Australia Group (for chemical weapons control; soon to be replaced by the Chemical Weapons Convention), the Biological Weapons Convention, and the Missile Technology Control Regime (MTCR).

restrictions on technology transfer that have for so long constrained trade and interaction between East and West.

A BINOCULAR VIEW OF THE ISSUES ASSOCIATED WITH DUAL-USE TECHNOLOGIES: TWO IS ENOUGH TO HAVE A FIGHT; IT TAKES MORE TO KEEP THE PEACE

Dr. Valery N. Spector
2nd Vice President, RAS Elorma Corporation
Russian Academy of Sciences
Merrill B. Walters
President, W & S Consultants, Inc. and former Director of Nuclear Planning
NATO International Staff

The complicated and often contradictory problems associated with the control of dual-use technologies have been the subject of three interacademy meetings. We have agreed that the rapid growth in systems based upon those technologies and the production of weapons systems based upon those technology developments are potentially a major threat to future world peace and stability. Four closely related issues were identified as the principal focus of our deliberations: export administration, defense conversion, "brain drain," and science and technology development.

In countering the proliferation of dual-use technologies, both the United States and the Russian Federation are like ships in troubled seas. Both ships are over burdened with arms and dangerous munitions. Both have been flagships of large portions of the world and both have decided to sell or ditch substantial portions of their armaments, even though faced with surroundings that are not always friendly. Ship Russia has sustained somewhat more damage, with AWOL deck hands, brain drain and damage to the power plant and hull—perhaps above the water line. Ship America was idling for awhile without steering while it changed command. Ship Russia's direction has been erratic because of a continuing fist fight on the bridge. Meanwhile, smaller and less powerful ships, through the capabilities offered by dual-use technologies, can pose a threat to the security of any ship on the seas.

This metaphorical description illustrates some oft he similarities in our situation. However, there are many unique differences in our economic, geographic and social structures that directly affect how each nation sees its security and the threat posed by proliferating dual-use technologies. For example, Libya has announced that the United States is its number one enemy. Likewise, Latvia refers to the Russian Federation as its primary enemy. Without deeper analysis, it would seem that both cases are like Krylov's fable about a small dog barking at an elephant. However, closer consideration shows very different circumstances indeed. Not many American citizens live in Libya, while a substantial part of the population of Latvia is Russian, which is being deprived of many of its basic rights. Libya is far removed geographically from the United States, while Latvia and Russia have a common border. The United States and Libya have never had a common military organization, but Latvia acquired a whole set of sophisticated conventional weapons when it gained its independence. Many of these weapons, as is the case in other newly independent states as well, will be dumped into the international weapons market, thus adding to the proliferation problem.

Even with a high level of desire and mutual understanding on both sides, some issues are very hard to bring to a common approach. For example, the wide range of differences in geographic areas of interest is clearly seen in the short illustrative list of countries contained in the following chart:

COUNTRIES OF PROLIFERATION CONCERN

For United States	For Russia	For Both
Argentina	Afghanistan	
Bolivia	Azerbaijan	
Brazil	China	China
Burma	Estonia	
Chile	Iran	Iran
China	Japan	
Columbia	Latvia	
Cuba	Lithuania	
India	Mid Asian Repub.	
Iraq	Moldova	
Iran	North Caucasus	
Libya	Pakistan	Pakistan
Nicaragua	Poland	
Pakistan	Romania	
Yugoslavia	Ukraine	
	Yugoslavia	Yugoslavia

In the current state of affairs, there is very little overlap in the list of countries which are of priority concern to both nations. However, if the expansion of the sale and use of technologically sensitive weaponry is to be precluded, the list of countries to be limited, in terms of sensitive dual-use technology and foreign trade, should be expanded. On the other hand, as forcefully stated by Dr. Rittenhouse of the General Electric Corporation in his report at the second interacademy meeting on dual-use technologies in May 1992, the number of controlled items should be reduced to only those that are most dangerous to preclude serious damage to the continued growth of the international economies and industrial cooperation. Balancing the restrictions and control required to counter proliferation of dual-use technology with the need for industrial and economic growth will be one of the more difficult issues to resolve.

Although the impact of the proliferation of dual-use technologies on their national security is seen differently by Russia and the United States, progress in the counter proliferation fight calls for both parties to change their attitudes and to attempt to see things as they are perceived by the other party. When this occurs, we feel that then there is a chance that this binocular view will develop a vision that is increased in power by two. Otherwise, mutual misunderstanding will continue to wreak havoc on the efforts to counter proliferation of dual-use technologies.

We are quite sure that not all hope of countering proliferation of dual-use technology is lost, and the very fact of the interacademy talks taking place indicates the desire to further our mutual issues, as laid out in our joint recommendations, to the attention of our respective governments. In spite of all the problems and differences, both governments must recognize the danger to world peace and stability posed by these dual-use technologies and take action to counter their proliferation. Meanwhile, we look forward to continuing our bilateral discussions in this stimulating, complicated, and very important area.

Papers Presented at the Second National Academy of Sciences-Russian Academy of Sciences Joint Meeting on Dual-Use Technologies

May 26-29, 1992

Washington, D. C.

A CONCEPTUAL APPROACH TO ADDRESSING DUAL-USE TECHNOLOGIES: A FRAMEWORK FOR U.S.-RUSSIAN DIALOGUE

Glenn Schweitzer
Director, Office for Central Europe and Eurasia, NAS

CROSS-CUTTING THEMES

During our planning meeting in Moscow, several themes cut across the specific topics which were identified for future discussions. I would like to comment briefly on these topics.

We quickly agreed that one overarching goal of international cooperation in addressing dual-use technologies is the "building of mutual confidence." But what do we know about confidence building?

To arms control specialists, this term has a distinct connotation based on years of effort in formal and informal negotiations to develop approaches that could reduce suspicions of the U.S. and Soviet governments over possible hostile intentions of the other superpower. Diplomats emphasized the importance of steps that could decrease the likelihood that the United States or the USSR would misinterpret "normal" peacetime military activities of the other country as activities being undertaken to set the stage for military attacks in the near future. They also have underscored the closely related objectives of building trust between the two countries and of reducing uncertainties and miscalculations in each country's assessment of the capabilities of the other. Among the many types of formal arrangements that address these overlapping goals are the communications hotline between Moscow and Washington, the procedures for warning of accidental launches of strategic weapons, the verification provisions of the INF agreement, and most recently, the declarations of biological warfare activities of the past.

Turning to our dialogue on dual-use technologies, an important objective would seem to be to building confidence that nations are using advanced technologies in ways they say they are using them and are not clandestinely diverting technologies earmarked for civilian applications to military applications. Given the diversity of technologies with dual-use applications, there are many opportunities for mistaken suspicions about motivations of other countries, and steps that encourage as much transparency as possible without compromising legitimate restrictions on military activities would be very welcome. Are there practical steps which can be taken to reduce the likelihood of technological surprises which result in major political or economic disruptions, or even more ominously, in war?

Building confidence is intended to enhance national security of nations. But the changing concepts of national security must be considered. Of course prevention of armed conflicts remains at the core of these concepts, but military threats do not seem to be as dominating a factor as in the past. Economic disparities among nations and frustrations over restricted access to international economic resources are at the root of many disputes. Disruption of ecological systems due to pollution and to the ravaging of biological resources has been described by some scientists as a threat to survival of no less significance than major wars. The AIDS virus raises new concerns over the safety of national populations. And food shortages continue to dominate the survival agendas of many countries.

How does this ever-broadening concept of national security relate to confidence building? Very simply, confidence must be instilled in many more parties than in the past. It is not enough simply for the generals or the intelligence services or even governments to be satisfied that they know what is happening throughout the world. The other parties which play a national security role must also have confidence in international intentions—the businessmen and financiers, the scientists and environmentalists, and even the farmers and doctors.

The industrial base of a nation is of great importance from a national security viewpoint. Not only is the size of the base important, but the composition of the base (and particularly capabilities to produce dual-use technologies) is critical. While the size of the armed forces of the larger countries may be shrinking, the desire to equip the new forces with the most advanced technologies increases. If such technologies also undergird commercial developments as well, the nation benefits accordingly. As to the smaller countries, a high technology industrial sector can have profound implications, both economically and militarily.

Finally, a word about the impact of the communications revolution on the way that nations interpret international developments. CNN can certainly help us focus on this topic.

Dual-use technologies have made the information revolution possible. At the same time, the rapid dissemination of information can lead to better understanding of the way dual-use technologies are being employed. Unfortunately, fragmentary information can also give erroneous impressions of the potential use of such technologies. In short, the new capabilities to transmit information around the globe both simplify and complicate efforts to build confidence among nations.

DEVELOPMENT AND DIFFUSION OF DUAL-USE TECHNOLOGIES

In recent years many advanced technologies developed within a number of countries have supported both military and civilian activities, and more are in various stages of development. Some of these technologies were initially developed for civilian programs and others for military programs. They were then adapted to serve dual purposes. Such dual-use technologies include (1) process technologies that are used in the manufacture of components for civilian and military systems; (2) technologies embodied in products that enhance the performance of military and civilian systems; and (3) know-how or applied knowledge that is necessary for the design, development, and manufacture of military and civilian products.

High speed computers, electronic detection and control devices, plastic and ceramic materials, aircraft and space systems, navigation and positioning equipment, precision machine tools, and specialized fermentation and chemical synthesis techniques are but a few of the many categories of technologies that have supported both military and civilian tasks. More technologies are added to the dual-use list each year, and more nations are increasing their capabilities to acquire and utilize such technologies. Thus, concerns increase over the possibility of diversion, and particularly clandestine diversion, to military purposes of technologies which have been developed, produced, or sold on the assumption that they will be used only for civilian purposes.

The United States and Russia have considerable experience in developing and applying advanced technologies for military systems, including many technologies which are also of current or potential civilian importance. At the same time the approaches to developing and controlling such technologies in the two countries have been very different. Indeed, the United States has been the leader in developing many advanced technologies that have been precluded by the west from export to the former USSR because of their applicability to military systems.

Thus, discussions among experts from these two countries with very different perspectives on the control of dual-use technologies should help clarify practical steps that might be taken by individual countries with different political and economic systems and by the international community as well to discourage the diversion to military applications of technologies intended for civilian purposes. At an appropriate time (given the wide interest in this problem) such discussions might be broadened to include experts from other countries. But, as a point of departure, informal U.S.-Russian bilateral discussions can be helpful both in improving mutual understanding of past approaches of the two largest military powers and in shaping the agenda for broader international discussions.

Realistically, many countries will continue and intensify their efforts to obtain advanced technologies both for military and civilian purposes. If military authorities identify a civilian technology of importance to them, they will attempt to acquire and use it. If civilian authorities become aware of a technology that will contribute to economic development, they will not willingly exclude the use of such technology simply because that technology might also have military applications. Radar systems are an excellent case in point. No country can be denied the opportunity to employ sophisticated radar systems at civilian airports while, at the same time, every military air force relies on radar technologies for air defense purposes.

However, it may be possible to develop steps to slow the unintended diffusion of civilian technologies to the military sector, or at least to alert the international community when such transfers are underway. Such alerts should help reduce surprises with destabilizing impacts. Also, if international trade in high technologies for civilian applications is to flourish, then building confidence among the many trading partners as to how the technologies will be used is very important.

BUILDING CONFIDENCE AND AVOIDING SURPRISES AMONG NATIONS

Nine discussion topics are being considered as a starting point for building confidence among American and Russian specialists concerning diffusion of dual-use technologies. These same topical areas might also be a useful starting point for engaging specialists from other countries in this type of dialogue.

Movement of Technical Specialists

Hundreds of thousands of scientists and engineers are involved in the design, production, and operation of high-technology systems throughout the world. Many of these specialists have skills that have been widely diffused throughout many countries and are regularly employed in the development and operation of civilian systems and low technology military systems. But a more limited number of specialists have unique knowledge and skills that are critical to the proper functioning of highly sophisticated military systems which are currently concentrated in only a few countries. The purpose of this activity is to begin to identify the types of specialists with these unique skills that only can be acquired through involvement in weapons programs and that are essential to the development and operation of advanced weapons systems.

Recently, international attention has been directed to skills related to nuclear weapons, and more specifically to the possible migration of Russian nuclear weapons scientists to other countries attempting to develop their own nuclear capabilities. This activity also encompasses skills involved in the development of non-nuclear weapons of mass destruction, command and control systems, and high precision weapons.

Once some of the most critical skills are identified, consideration can then be given to the mobility of personnel with these skills. Traditionally, a Soviet specialist has been committed to a single professional position for an entire career. The situation is different in the West, where specialists often move within and between the military and civilian sectors. The situation is changing, although slowly, in Russia. The key question then will be whether systems can and should be developed to monitor the movement of critical personnel within or between countries.

Encouraging Openness in Basic Research

The greater the degree of openness of basic research, the less likelihood of surprises of discoveries with military significance. Of course many countries will continue to support classified military research programs, but classification should be directed primarily to the applied aspect of research. International cooperation provides an excellent vehicle for promoting openness in basic research, but even the results of research programs that do not involve international cooperation should be disseminated broadly both to benefit science and also to instill confidence in the peaceful motivations for basic research.

Separation of Research for Civilian and for Military Purposes

Most countries have separated classified research for military purposes from unclassified research for civilian purposes, and this pattern undoubtedly will continue. However, in the area of dual-use technology, separation of military and civilian research may not always be desirable since progress on one front can help progress on the other front. In some cases, separation may not even be feasible since military and civilian applications may require identical products, or military applications may simply require more stringent performance standards (based on tighter quality control) than the civilian applications. Nevertheless, separation of military and civilian applications, when possible, should simplify monitoring civilian activities in a way that builds confidence that these activities are peacefully oriented and not simply well springs for military exploitation.

Clearly, international scrutiny of all unclassified applied research activities is not possible. It may be useful in this regard to identify technologies that are choke points for military systems, that is technologies that provide critical components in the functioning of systems which cannot easily be duplicated and without which the systems simply will not operate. Concentrating attention on these technologies might then be a useful orientation for international efforts designed to build confidence as to the motivation underlying applied research activities.

Case Studies of Dual-use Technologies

Case studies of very specific technologies, such as previous efforts to use fuel cells and current plans to develop organic semiconductors, can clarify many of the issues that will arise in trying to develop approaches that help build confidence concerning the uses of advanced technologies developed for civilian purposes. Different types of process and product technologies which are at different stages in their development should be selected for the case studies.

Reports by Industrial Enterprises

All governments require industrial enterprises to file a variety of reports for tax, environmental, medical, and other purposes. Usually these reports take the form of statistical information and narrative descriptions of the activities within the enterprises. Also, in the West annual company reports are used for external public relations purposes as well as for business purposes. Within Russia, industrial reports designed for public consumption are gaining increasing popularity as secrecy requirements are relaxed and as companies move toward privatization and intensify their search for new markets both at home and abroad.

Reports should be available to provide the public with a clear sense of the activities carried out within individual industrial enterprises. Even for classified activities, reports can be helpful in describing in general terms the types of activities within specific facilities. Such reports can be an important aspect, and indeed a starting point, in building international confidence concerning the use of technologies for civilian purposes. A degree of standardization in the types of information which are made available on a worldwide basis would be particularly helpful in this regard.

Economic Aspects of Conversion

If enterprises are to change from military to civilian production, they must replace their previous dependence on defense contracts with new approaches to financing, marketing, and profitability. Unless such a transition is successful and clear to all, international suspicions will linger that conversion has not really taken place and that technologies continue to be used for production of military products. At the same time, military authorities usually retain an interest in old military production facilities even as they begin conversion, lest changes in military requirements call for reconversion to meet new military demands: This tendency underscores the importance of persuasive economic evidence that conversion activities are genuine and permanent.

The economic aspects of converting military production facilities to civilian oriented facilities are complicated even in the West, where a market economy is the way of life. In Russia, with no historical experience in operating within a market economy, conversion is being accompanied with the invention of new economic concepts and institutions, an extraordinarily difficult task. Successful conversion of those facilities with dual-use capability is critical to building confidence that technologies are not being diverted from civilian to military applications, and successful conversion is highly dependent on successful economic performance.

Detailed studies of enterprises in the process of conversion should be helpful in clarifying the difficulties which inhibit rapid progress, organizationally and technologically, and also in identifying indicators of the likelihood of economically viable conversion.

Trends in Export Control

Both the United States and the former USSR have had considerable experience in limiting the export of technologies considered important for military systems. The Soviet approach was to classify those technologies which were particularly sensitive, whereas the United States relied on a system of controlling exports of selected but unclassified dual-use technologies as well as on classification of particularly sensitive military technologies. In addition, COCOM served as a multilateral forum for coordinating policies of the western countries, whereas COMECON presumably played a less significant role in promulgation of policies of the former USSR related to the control of exports of militarily sensitive technologies.

A review of past and current approaches of the former USSR and the United States to the control of exports of dual-use technologies should be helpful in identifying future opportunities and problems. A particularly important future consideration is the transfer of dual-use technologies among the former republics of the USSR and the policies of Russia in this regard. Also, consideration of the present and future role of COCOM and other international regimes established to address other non-proliferation concerns should be helpful in considering approaches to limit export of strategic technologies to the less developed countries as well as controlling selected technologies within an East-West context.

Verification Schemes for Monitoring Dual-Use Technologies

Innovative approaches to verifying that dual-use technologies intended for civilian applications are not being diverted to military activities should be considered. One priority might be to confirm the accuracy and completeness of information about research and industrial activities provided by participants in systems to control and/or monitor the diffusion of dual-use technologies. Since these technologies have so many civilian applications throughout industrialized economies, on-site verification schemes need to be carefully designed to avoid unacceptable intrusiveness. As previously noted, perhaps technological choke points or specialized technical skills can be identified and can serve as primary targets for verification activities.

Lists of Important Technologies

For many years the United States and other Western countries have maintained a variety of lists of dual-use technologies that are considered to be militarily sensitive, and these lists have been important in determining export control regulations. The former USSR also presumably had lists of those technologies considered important for national security purposes. A joint review of existing national and international lists of technologies that are now considered to be militarily sensitive should be helpful in clarifying the concerns in the two countries and in reaching a common level of understanding of the types of technologies which are of special interest.

SETTING THE STAGE FOR FUTURE ACTIVITIES

Following discussions of the foregoing topics, specialists from the two countries should be in a much better position to determine the desirability and feasibility of more concerted national and international efforts to address the spread of high technology products developed for civilian purposes but with important military applications as well. Some technologies will continue to be used for military purposes, but others may not. In the latter case, international cooperation and trade should be able to thrive if not encumbered with suspicions and false allegations.

Many other related efforts are underway, particularly with regard to preventing the proliferation of nuclear weapons technology and to reducing the lists of technologies that are embargoed for export from West to East. This effort is intended to complement these other activities that are being pursued primarily through intergovernmental channels by emphasizing those technologies which are still in their early stages of development, international cooperation that encourages openness, and verification systems which rely on the monitoring of both economic and physical indicators of activities of concern.

JOINT CONCEPT OF U.S. AND RUSSIAN PROVISIONS FOR THE ENSURANCE OF GLOBAL STABILITY UNDER CONDITIONS OF THE NEW WORLD ORDER

General Oleg K. Rogozin (retired)
Principal Research Scientist, RAS Elorma Program
Former Deputy Chief of Procurement, Soviet Ministry of Defense
Professor Valery N. Spector
Vice President, RAS Elorma Corporation

PREAMBLE

A New Megatrend of the 1990s: Transition from the Arms Race to Defense Sufficiency

Megatrends 2000: Ten New Directions for the 1990s, by J. Naisbitt and P. Aburdene, lacks a vital aspect which makes predictability for what is coming less than doubtful. We feel justified to say that one of the major megatrends now is a transition from a rigid armed counterpose of superpowers to a state of defense sufficiency, when the primary task of armed forces becomes a guaranty of national survival.

Bipolar Strategic Arrangement Preservation as a Geopolitical Imperative

Strategic nuclear forces of two great powers—the United States of America and the Soviet Union—have evidently become a decisive factor for the almost half century of calm on the world level, as their mutual deployment would have brought the world to a total catastrophe without victors or losers. The strategic nuclear forces, the ban on deployment of which has not yet become an absolute political and military imperative, have mainly caused limitation or, to be more precise, impossibility of the traditional wars between nuclear states, as nobody could have given reasonable guarantees for non-deployment of a tactical, or in later stages, strategic nuclear weapon by a losing party, if it were on the brink of a national catastrophe.

Expansion of the "Nuclear Club"

The dominant strategic balance of nuclear forces of the United States and USSR after World War II helped to maintain a time-tested international bipolar geostrategic stability, which prevented large-scale regional and world wars. However, the principle accepted in the U.S. and USSR of "the fewer fingers on the nuclear triggers, the better" was soon violated. The dialectics of universal development are such that more and more countries are joining or trying to join the "nuclear club." Great Britain, France, and China have been members of this "club" for a long time; later Israel, South Africa, India and Pakistan also developed nuclear weapons. Iraq, Argentina, Brazil and North Korea may soon also have nuclear weapons. The fact that many countries which are trying to reach their own nuclear triggers did not sign the non-proliferation treaty of March 5, 1970, is troublesome.

The main attributes of nuclear weapons are their carriers (ballistic and aeroballistic missiles, cruise missiles, artillery shells, and others). The rapid development of such carriers is noticeable in many developing countries. In 1989, about 20 countries had ballistic missiles, which are the least vulnerable in flight (among all types of carriers). In recent years Egypt, Iraq, Iran, North Korea, Pakistan, and Saudi Arabia developed such missiles. Twelve countries are currently actively developing such missiles. This process is aided by the ill-advised policy of the developed countries, including the U.S. and the former USSR, of increasing the number of types and sizes of carrier rockets, granting licenses for their production, providing scientific-technical consultations and support. A chain reaction is going on in the world and things have even gone so far that several Third World countries (Argentina, Brazil, and others) themselves became exporters of carrier rockets.

Multipolar Geostrategic Set Up - A Way to Apocalypse

Under the conditions of a perilously rapid development of missile and nuclear technologies by the Third World countries and the disintegration of the USSR, the world's bipolar geostrategic stability is starting to erode, which may cause serious and unpredictable military and political consequences, especially in the Islamic world (including the territories of the former USSR), and in the Asia-Pacific region.

Creation of a multipolar geostrategic nuclear world system is a direct path to an apocalypse, since several Third World states with newly developed or almost developed nuclear weapons experience a much higher temptation to resolve territorial, religious-ethnic and other problems by military means. Kuwait's annexation by pre-nuclear Iraq and continuous military conflicts between India and Pakistan in the Kashmir region are just two examples.

Are Nukes the First Strategic Priority for Technologically Advanced States?

The struggle for the strategic stability of the world community (or more precisely, for its physical survival) cannot be limited just to nuclear weapons, since modern conventional high-precision long-range weapons are also formidable strategic means of war and international terrorism.

This is caused by the huge power, chemical, and radioactive potential accumulated in the economically developed countries (nuclear power plants, chemical and oil processing industries, water-engineering systems, etc.). Their deliberate or provocative destruction by high-precision conventional weapons may cause catastrophic consequences on the regional and global levels. Because of this, under these perilous conditions of changing strategic stability, the world community should decisively move from a multitude of declarations on universal disarmament and endless cuts of nuclear and conventional weapons to strict legal measures under the aegis of the United Nations and forceful measures of self-defense. The two superpowers—the United States and Russia—should become leaders of this process.

THE MAIN PRINCIPLES OF SECURING THE WORLD'S STRATEGIC STABILITY BY THE UNITED STATES AND RUSSIA

1. Exerting highest influence from the United States and Russia to secure the world's strategic stability, and maintenance by these two superpowers of the time-tested world order that prevented conventional large-scale and world wars.
2. Strengthening of mutual trust between the United States and Russia in the military-political and strategic areas, joint development and adoption of agreed decisions on problems of international and national security, openness and mutual assistance in the areas of military-technical construction, which will eliminate mutual pseudo-threats and prevent a needless arms race between the superpowers.
3. Adoption—under the aegis of the United Nations, by the world's most advanced nations, and under the leadership of the United States and Russia—of effective measures designed to block the build up of strategically dangerous nuclear and conventional weapons in the third world countries, especially in countries with non-democratic authoritarian regimes; banning the development in any country of new, even more inhumane weapons of mass destruction; and reduction by treaties or under compulsion of stockpiled strategic weapons by involving all countries in this process.
4. Establishing under the aegis of the United Nations systems of international control, monitoring, communications and data transfer, including the following:

- a missile attack warning system, capable of providing timely warning to the world community about an accidental or deliberate launch of missiles, and able to determine the coordinates of the launch and detonation sites, and the details about the flight path of the weapon units;
- a system of monitoring outer space, capable of warning countries about military changes in outer space, and also able to monitor compliance with international treaties on space use;
- monitoring of testing of strategic nuclear and conventional weapons in various physical environments;
- an automated command point of the United Nations for receiving, processing and transmitting data used in the total assessment of the strategic situation in the world.

5. Creating a global system of anti-missile defense for intercepting deliberate and accidental launches of single or small groups of ballistic missiles.
6. Setting up a joint U.S.-Russian center for verification of non-proliferation of strategically dangerous technologies.
7. Creating supervisory bodies accountable to the International Atomic Energy Agency (IAEA) for monitoring the development of new nuclear weapons systems in Third World countries.
8. Organizing international endowments for social and professional support of scientists and leading specialists in the fields of nuclear weapons and space technology.
9. Internationalization of basic research in the areas of material properties, physics, chemistry, and biology, including the following:

- initially joint Russian-American scientific projects, related primarily to the indicated fields;
- adding to these programs scientists from other countries through retraining and reorientation to basic and advanced research aimed at creating a foundation of collective development and collective security;
- widening the scope of projects to include applied research aimed primarily at the development and international unification of waste-free and resource-saving technologies, creation of systems of regional and global ecological monitoring, systems of recultivation and recuperation of the biosphere, lithosphere, hydrosphere and atmosphere, systems of repressive control of the technospheres.

MAIN TYPES OF STRATEGICALLY DANGEROUS ARMAMENTS

The following types may be, from our point of view, referred as a priority among the most strategically dangerous armaments:

- All nuclear strategic, operational-strategic, operational-tactical and tactical warheads and means of their delivery (ballistic, aeroballistic, and aerodynamic missiles launched from the ground, sea, aircraft or outer space with flight distance over 500 kilometers, and strategic aircraft);
- missile-carrying ships with missile range over 700 kilometers, operational-strategic "stealth" aircraft with an operational radius of action over 500 kilometers, striking (offensive) space and aerospace crafts, equipped with laser, particle beam, nuclear, and other air-to-surface weapons, also other types of mass destruction weapons (chemical, bacteriological, radio-frequency, ultrasound, etc.) and means of their delivery regardless of their range.

THE MOST IMPORTANT TECHNOLOGIES TO BE RESTRICTED FOR TRANSFER TO OTHER COUNTRIES

Technologies and scientific-technical documentation that should not be transferred to other countries include the results of basic, applied, and design research in the area of developing new, and improving existing, types of following weapons:

- nuclear weapons and weapons based on new physical principles;
- radar, television, infrared, laser, correlation (by area relief and target "portrait"), radiometric, and combined self-guided warheads for guiding high-precision strike weapons;
- thermovision systems and control (guidance) devices for all-weather and around-the-clock missiles, and guided bombs;
- low visibility aircraft (airplanes, missiles, etc.), primarily stealth aircraft;
- low specific density and corrosion resistant structural and composite materials for aerospace and missile technologies;
- optical and optoelectronic devices for control and guidance of strike (offensive) weapons;

- systems for processing signals of various physical origins;*
- high-precision laser gyroscopes;
- microelectronics and miniature thrusters;*
- supermini and onboard computers;*
- cryogenic engineering and fuel for rocket engines;*
- hydroacoustic systems for surface ships and submarines.*

BASIC MEASURES TO PREVENT UNCONTROLLED "BRAIN DRAIN" FROM THE FORMERSOVIET UNION

To prevent the employment of scientists and specialists from the former Soviet Union (primarily scientists from Russia) for the accelerated development of strategically dangerous weapons in a number of Third World countries, it is necessary to design a balanced and coordinated system of measures, which could include the following activities:

- a directed social and economic support of primarily Russian scientists and specialists during the period of transition from centralized to market economies taking place in the states of the former Soviet Union;
- reorientation of scientists and specialists who used to work for the military-industrial complex into other research work that would be similar in form and content, and their guaranteed employment, mainly in their own country;
- establishment of controlled contractual migration to developed countries and contractual assignments through the United Nations to developing countries for conducting civil research aimed at reconstruction and development;
- use of their knowledge and experience by involving them in solving ecological problems, primarily related to the accident at the Chernobyl nuclear power station and other industrial accidents, and disposal of weapons and munitions according to the conversion plans and reductions in armaments and armed forces;
- use of these specialists in international projects, primarily joint projects with the United States, designed to create and develop technical systems of global security;

* designates equipment and technologies that may be classified as dual-use technologies: their export and information transfer should be controlled within the framework of agreements on dual-use technologies and should not include their militarized versions.

- participation in joint projects with the United States and other developed countries aimed at reconstruction and development by conducting theoretical and applied research of a peaceful nature;
- development of international exchange systems concerning science and technology, including retraining of scientists and specialists, on the job training, support of scientist participation (primarily Russian), in international and regional scientific functions (congresses, symposiums, conferences, seminars, expositions, and science schools).

BASIC TRENDS IN THE DEVELOPMENT OF MECHANISMS FOR CONTROLLING THE EXPORT OF DUAL-USE PRODUCTS

General Remir F. Stepanov (retired)
Head of Department, International Fund for Social and Economic Reform
Former Director of Export Control, USSR

A process of re-examination is currently under way regarding concepts and views on many regional and global problems of our planet and the role of various countries and blocs in today's rapidly changing world. We are witnessing the formation of structures of the new world order based on cooperation and greater trust. Greater attention is thus being focused on the search for means of resolving problems of the nonproliferation of weapons of mass destruction (nuclear, chemical, and biological weapons, as well as their delivery vehicles, particularly missiles). The further spread of these weapons could lead to an increase in the destructive consequences of regional conflicts and to a greater risk of global catastrophe. Graphic confirmation of this point was provided by the war in the Persian Gulf.

Under present conditions, export control is one of the basic instruments by which various decisions regarding the nonproliferation of weapons of mass destruction are carried out in practice. This report will review problems associated with improving export control with regard to the nonproliferation of various types of weapons of mass destruction. In addition, this report details the reasons why our country should participate in international control mechanisms and formulates proposals for the development of a strategic regulation system in Russia.

SPHERES AND FORMS OF INTERNATIONAL AND DOMESTIC CONTROL

Control of weapons of mass destruction can be divided into three main areas: nuclear weapons and their components, chemical and biological weapons, and missiles and the technology used in their manufacture.

The nonproliferation of nuclear weapons is primarily ensured by means of international and national controls over the export of nuclear materials and technologies. Eight nations, including the USSR, the United States, and Great Britain, agreed in 1974 to establish controls on exports of nuclear materials. In connection with this agreement, the signatories drew up a list of controlled materials, equipment and other components used for the creation of nuclear weapons. Subsequently added to this list were components of gas centrifuges, which are used in uranium enrichment. As a result of mutual consultations, 50 nations have now developed "Guiding Principles for Nuclear Exports" and officially have declared their intention to follow these guidelines. Under existing agreements, the states which export nuclear materials and technologies have instituted their own domestic measures to control these shipments.

AUSTRALIA GROUP

In 1984, Australia, Belgium, Canada, Denmark, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Switzerland, Great Britain and the United States joined together to form the Australia Group, which aims to limit the proliferation of chemical and biological weapons. A representative from the European Community also participates in the group's activities. The aforementioned nations have drawn up a list of components which can be used in the production of toxic substances. This list consists of 50 items and is intended to inform firms operating in Australia Group member-countries of the fact that these chemicals can be used to produce both civilian and military products (such as chemical weapons).

Nevertheless, the Australia Group has not created any effective international control mechanism. Our country does not participate in its work on an official basis.

CONTROL OF MISSILE PROLIFERATION

Control of missile proliferation has a very short history. In April 1987, the United States, Great Britain, France, West Germany, Canada, Japan and Italy established a committee for the control of missile proliferation and agreed to basic control principles, which were set forth in a document entitled the Missile Technology Control Regime (MTCR). This committee was subsequently joined by Australia, Belgium, Denmark, Spain, New Zealand, Norway, the Netherlands and Luxembourg. A total of 16 nations currently participate in the effort to control missile technologies. Furthermore, the United States also carries on a unilateral control over a broader list of missile technologies than that of the above countries. Our country is not presently among the participants in the international missile control regime.

However, the international and national control systems currently in place have not managed to prevent the proliferation of weapons of mass destruction, primarily because the existing control mechanisms do not cover all issues of vital significance in the area of nonproliferation. For example, the MTCR includes only missiles themselves, essentially ignoring missile technologies used in civilian space programs that might also have broad military applications. It must be noted that practically all missile technologies have civilian and military uses.

The control mechanisms existing in foreign countries are also imperfect. Due to the fact that some agencies charged with export control make export expansion their top priority and view control as a secondary factor, many export control services remain understaffed and continue to experience financial shortfalls.

As for the position of Western firms actively engaged in making illegal shipments, one reason for this situation is that the punishment for violating export control regulations is too small in comparison with the profits obtained through these deals.

As a result, the strategic regulation of exports has not managed to check the increasing transfer to developing countries of technologies used in the production of weapons of mass destruction. It is now known that 267 major foreign firms were involved in the build up of Iraq's military potential alone. A total of 97 private companies from Germany sold modem weapons and military technologies to Iraq, along with 31 companies from Great Britain, 23 from Austria, 22 from the United States, and 19 from France. Firms from other Western European countries, Japan, China, India, South Africa, Brazil, Argentina, and Egypt also became involved in this profitable business. German firms, generally operating through Switzerland, have supplied a wide range of nuclear materials, equipment, and technologies to India, Pakistan, and South Africa. Brazil has created the Sonda-4 missile, which has a range of about 600 kilometers, with assistance from German firms as well. Pakistan has begun producing missiles with technical help from France and the United States. Operating illegally through Romania, Israel has obtained heavy water from Norway. These are but a few examples. Similar shipments have also been made from our country. All of this has led to the accelerated proliferation of weapons of mass destruction.

Although there are officially still only five nuclear powers in the world (the United States, Russia as successor to the USSR, Great Britain, France, and the People's Republic of China), information on the existence of nuclear weapons in other countries is so contradictory that estimates of the number of members of the "nuclear club" range from nine to as high as thirteen, according to some data. Based on current assessments, this club already includes Israel, India, Pakistan, South Africa, and even Argentina, Iran, North Korea, and Taiwan. In addition to the aforementioned countries, specialists believe that there are at least ten more countries which could produce nuclear weapons in the next few years. At the start. of the twenty first century, 30-40 nations will have nuclear arms production capability, half of which will be Third World countries.

By mid-1991, only four states officially possessed chemical weapons: the former USSR, the United States, Iran, and Iraq. However, according to a report from the U.S. Agency for Arms Control and Disarmament, almost twenty more countries are suspected of having chemical weapons or trying to obtain them. There may be around ten more nations in this group by the end of the century. The proliferation of chemical weapons is facilitated by the fact that high technology is not required for their manufacture.

Given such a course of events, as soon as the beginning of the next century we could see a notable increase in the number of countries with nuclear missiles and chemical weapons. As a result, the military-political situation in the world would be exacerbated, instability would increase, and the likelihood of nuclear confrontations would rise.

Therefore, foreign countries have recently been taking additional measures to improve strategic export regulation. For instance, on the initiative of the United States. and Japan, 26 nations organized the Group of Nuclear Materials and Dual-Use Equipment Suppliers in March 1991. This group is currently compiling a list of technologies which are prohibited for export. The list is expected to be in final form in February 1992. The measures which have been taken at the international and national levels have already led to a certain reduction in the pace of a number of developing countries' programs for the production of weapons of mass destruction.

RUSSIA AND MISSILE PROLIFERATION

Our country has yet to participate in any specific or practical fashion in the aforementioned measures aimed at strengthening the regime for the nonproliferation of missile and chemical weapons. Meanwhile, the transformation of the Soviet Union into the Commonwealth of Independent States (CIS) might even accelerate the spread of weapons of mass destruction. Let us recall that in the 1980s, the USSR proposed the creation of an international mechanism similar to the International Atomic Energy Agency as a possible means of addressing the missile question. This mechanism would prohibit missile proliferation, but at the same time would also not prevent interested countries from obtaining missiles for peaceful purposes. A number of missile-exporting nations have been holding consultations on this question since 1987.

As noted above, the proliferation of weapons of mass destruction is primarily based on illegal sales of the technologies used in their production, as well as certain parts and components, by foreign private companies. Under the current conditions of ongoing privatization, this is becoming a critical problem for our country as well. Furthermore, it is also complicated by the fact that the newly created government bodies in the Newly Independent States lack sufficient experience in regulating the export activities of private enterprises in the area of military equipment and weapons.

As previously noted, export control with the aim of curbing the further proliferation of weapons of mass destruction is today a topic of serious consideration in Western countries. In this regard, it appears that the CIS must also develop and set forth its position on this fundamental question as soon as possible.

Mental inertia is creating a situation in which many in our own government and abroad do not fully realize the danger of the impending uncontrolled proliferation of today's destructive types of weapons. If we do not resolve the problems of nonproliferation with the means currently at our disposal, and if we find no other way of neutralizing new members of the "nuclear missile club" except by creating an anti-missile defense system ("highly accurate" or otherwise) on our own or with the NATO countries, the CIS will be placed in a very difficult economic position. Setting up an anti-missile defense system capable of protecting the entire territory of the former Soviet Union would require enormous expenditures and could bring about further exacerbation of the country's socioeconomic problems.

Considering all these factors, it is necessary first of all to maintain and strengthen the unified system existing under the former Soviet Union for export control over shipments of weapons of mass destruction and the technologies for their manufacture. At the same time, it would be advisable to ensure a sufficient degree of control throughout the territory of the former USSR. This would be in the interests of both members of the CIS and sovereign states which are not members, as the further uncontrolled proliferation of weapons of mass destruction could result in decreased security for all of them. Foreign experience attests to this fact. For instance, in connection with their plan to create a common market in 1993, the countries of the European Community have raised the question of forming a unified control system. Therefore, it is envisioned that a fully justifiable insertion be made in the text of the treaty on economic cooperation within the CIS calling for unified export control over shipments of weapons and the technologies used in their manufacture.

Within the new framework and on the basis of critical consideration of accumulated export control experience in the West, it is also essential that we improve our own control services charged with ensuring the nonproliferation of strategic weapons. The experience of foreign countries in recent years convincingly attests to the fact that export control instituted only at the national level is insufficiently effective. Therefore, while striving for the expansion of foreign economic ties, we must now consider establishing a two-tier export control system, both at the national level and within each enterprise. This system must be focused primarily on goods and technologies used to produce nuclear missiles and chemical weapons.

Meanwhile, without comprehensive multilateral agreements, preventing the further proliferation of weapons of mass destruction will obviously be impossible in practice. Representatives of Western governments are increasingly stressing their interest in joint activities. It is in the interest of the new Commonwealth of Independent States to accept the proposals which have been made. However, in doing so we must ensure that such cooperation does not antagonize the developing countries. The inclusion of our country in international export control regimes should be combined with active efforts on disarmament, as the intensification of export control in conjunction with the weakening of disarmament efforts would likely evoke a negative reaction from the developing nations. It should also be stated that multilateral export control would not hinder the transfer of technologies and goods for civilian uses.

In Western countries, there is currently a broad discussion under way about what the export control system should be and what mechanisms should be put into play in order to deal with problems of nonproliferation. Specifically, it has been proposed that existing international regimes for the control of weapons of mass destruction be strengthened to ensure that transfers of modem varieties of these weapons are monitored.

A new monitoring mechanism could even be created if necessary. However, it is our view that resolving the problem of nonproliferation is hardly possible without creating a representative international organ under the aegis of the United Nations Security Council. This body, which would include primarily such countries as the United States, the CIS, Great Britain, France, Germany, Japan, China, and Italy, would be charged with coordinating the activities of existing systems for the control of nuclear, chemical and missile weapons and facilitating communications with national control systems, including at the enterprise level.

In discussing the future nonproliferation mechanism, Western research studies often express opinions on the participation of COCOM in the process of strategic regulation aimed at preventing the spread of weapons of mass destruction. COCOM members include the United States, Great Britain, France, Germany, Canada, Italy, Spain, Portugal, Belgium, the Netherlands, Luxembourg, Denmark, Norway, Greece, Turkey, Japan, and Australia. This export control system was created and developed as an auxiliary instrument to NATO intended to regulate shipments to the CIS and allied states of goods and technologies which might be used to strengthen their military potential. Let us recall that COCOM focuses its control efforts in three main areas: weapons and military equipment; machines and equipment necessary to produce or utilize nuclear energy; and dual-use goods and technologies.

According to existing information, the United States has raised the question of expanding COCOM's sphere of operations by adding arms proliferation control to its list of responsibilities. We believe that today it is expedient to speak not of the expansion of COCOM's sphere of operations, but of its transformation into an operating arm of the above-proposed UN-sponsored international body which would be charged with handling weapons proliferation issues. Furthermore, if the CIS is truly integrated into the world economy, there will be no more need for many of the functions which COCOM currently performs. According to studies conducted by foreign and Russian specialists, this committee represents a well-organized system which has operated rather effectively over a long period of time and has amassed significant experience. Changing the functions of COCOM would permit a certain easing of export controls with regard to firms which supply our country with modem technologies and goods.

It is envisioned that the new international body would have both a mechanism to allow on-site inspections to uncover violations of the weapons nonproliferation regime and an effective system for ensuring compliance. A certain amount of experience has already been gained in compliance assurance and inspections of nuclear missile and chemical weapons sites, including efforts to ascertain Iraq's military potential.

BASIC CONCLUSIONS AND RECOMMENDATIONS

Existing international and national controls over the export of nuclear materials and technologies, chemical elements and missile technologies—our primary means of ensuring the nonproliferation of weapons of mass destruction—have demonstrated their low level of effectiveness. In addition, current efforts to prevent the further spread of weapons of mass destruction are insufficiently coordinated among such countries as the United States, the CIS, Great Britain, France, Germany, China, and Japan. This same lack of coordination is evident at the national level, among the various agencies which carry on control-related activities. The control mechanisms themselves are imperfect. They are not always focused on goods and technologies which can be directly and productively used to create weapons of mass destruction.

Existing export controls have been unable to prevent the increasing transfer of technologies for the production of nuclear missiles and chemical weapons, primarily from large Western European or American military-industrial companies to the developing countries. This has led to the accelerated proliferation of weapons of mass destruction. This process has begun to take on a qualitatively new character. Whereas in the early 1980s developing countries largely bought finished products (various types of weapons of mass destruction), in the second half of the decade they began relying primarily on the acquisition of technologies to manufacture these weapons themselves. Thus, in the period 1985-1991 alone, 26 nations acquired missile technologies and initiated their own programs for building these types of weapons. Of the 22 countries which have ballistic missiles (besides the CIS, the United States, Great Britain, France, Germany and China), 15 more will be capable of producing them independently by the end of the century. A similar situation is developing with regard to nuclear and chemical weapons as well.

The transformation of the Soviet Union into the Commonwealth of Independent States might accelerate the proliferation of weapons of mass destruction, as there is still the possibility of the appearance of additional newly independent countries with nuclear missiles, chemical and bacteriological weapons, and the technologies for their manufacture. First, this would increase the number of potential weapons technology suppliers. Second, it would complicate the joint decision-making process.

We believe that under changing world conditions, the nonproliferation of weapons of mass destruction will be no less important than issues regarding further strategic arms reduction. In this regard, nonproliferation must be accorded higher priority in the policies of our country and of the leading nations of the world. The nonproliferation of weapons of mass destruction must hence be viewed as the most important element in the national security of the Commonwealth of Independent States.

In order to work out a general policy both on export control and on the nonproliferation of weapons of mass destruction, it would be expedient to create a special body including representatives of all the states in the CIS and a number of other agencies. This body must have sufficient financial, material, and human resources and be focused primarily on goods and technologies directly used in the manufacture of weapons of mass destruction. Considering the experience of foreign agencies and the significance of the problems with which it will deal, this intergovernmental body should be under the direct jurisdiction of the country's president.

In our view, it is vitally important to develop and pass a law on export control, that is generally analogous to existing American legislation on this topic. The law must clearly define the spheres and forms of strategic regulation, including in the area of weapons of mass destruction. It must also divide and assign authorities and functions to the various governmental bodies in the CIS. This will also increase the international standing of our country and make our foreign partners more willing to work with us on resolving rather delicate questions. It would be advisable to publish the export control lists so that they might be used by our manufacturers in their day-to-day export business.

In the international arena, the CIS must engage in active cooperation with the leading countries and declare its willingness to participate as an equal partner in existing multilateral export control mechanisms regarding weapons of mass destruction. This is particularly important in view of the fact that many Western specialists view our country's participation in the multilateral control system for weapons nonproliferation as one condition for easing the export regime on shipments of up-to-date types of equipment to the CIS. It appears that such an initiative on our part would be greeted with satisfaction, since Western nations interested in coordinating their nonproliferation activities with the CIS are currently discussing various ways of improving export controls on weapons of mass destruction. A possible first step might be a declaration of willingness to take part in joint activities to improve the effectiveness of existing export control regimes regarding nuclear, chemical and missile weapons.

We believe that the CIS should support the idea of creating a body under the aegis of the UN Security Council to address the nonproliferation of nuclear missiles and chemical and bacteriological weapons. This body must include an inspection mechanism, as well as an effective means of ensuring compliance. COCOM might be used as the operating arm of this Security Council organ.

Finally, we must remember that the West and particularly the United States will be closely monitoring the actions of the CIS in this area and modifying their own policies in accordance with what they observe. This being the case, an insufficiently responsible approach to the question of strategic regulation will ultimately hinder the integration of our country into the world economy. It is therefore in our interest to study carefully and utilize the experience amassed in similar export regulation efforts in the West in order to strengthen our own control services.

CONTROL OF DUAL-USE TECHNOLOGIES: A BUSINESSMAN'S RECOMMENDATION FOR PRESERVING THE MILITARY AND ECONOMIC SECURITY OF THE UNITED STATES

J. D. Rittenhouse
Senior Vice President for Technology Programs
General Electric Company

INTRODUCTION

Perhaps what is most difficult to understand about the control of dual-use technologies is the relationship between U.S. government and the U.S. industrial base; yet it is this relationship (or the lack thereof) which will form much of our policy in this area. The following comments on the separateness of the U.S. government and industrial sectors are intended to describe what "free market" means in both the commercial and defense industrial base sectors. This separateness is different from other democratic free market countries and is certainly different from the background of our CIS colleagues.

This separateness can be brought into focus by characterizing the attitudes and environment of each business sector—commercial and defense.

Commercial Sector

- Exists in a price-driven competitive environment.
- Believes profit is a noble goal—the more the better. Profit is based on price competition, both domestically and internationally.
- Hates regulation and interference by the government and feels regulation is directly impacting our international competitiveness.
- Does not have a uniform or constant viewpoint. Competitiveness and antitrust laws block collective demands on government policy until impact has occurred (e.g., the semiconductor industry and automotive industries).
- Feels constraints on export of dual-use technologies significantly impact our global competitiveness—puts economic security ahead of military security.

Defense Sector

- Exists in a cost-driven competitive environment.
- Is constrained in profit by a large set of regulations. Profit is based on cost, not price, except in international sales.
- Reluctantly accepts regulation as a demand of the public, but feels the bureaucracy is out of control.
- Competitiveness dictated by law blocks collective demand for reform.
- Feels laws which restrict personnel movement from business to government sector have significantly impacted capability of DOD personnel.
- Has no consensus perspective on dual-use technology export policy.

Finally, government participation in the economic condition of the U.S. has varied significantly. While regulation has grown, impacting detailed costs of business (1980-1990), at the same time deregulation (meaning more competition) of the communications industry has been a significant change, and our current executive branch has a hands off attitude (i.e, no industrial policy) which is at a peak right now.

This is in contrast to the government participation during the pre World War II era. In the author's opinion, the CIS needs to understand that our current long term economic condition is fundamental to our attitude toward control (or non-control) of dual-use technologies, and on our attitude toward the role of government in our free market system.

WHAT ARE DUAL-USE TECHNOLOGIES?

As a first step toward recommendations concerning control of dual-use technologies, we need to understand which technologies will be most critical *considering* the most likely threats to the United States (the author believes these bear a strong resemblance to those facing the CIS); and which part of the industrial base (commercial or defense) is currently providing leadership in that technology area.

To facilitate the discussion, technology areas are divided into three categories:

- First, those dual-use technology areas in which the commercial sector provides leadership. These include:
  - Solid State Devices
  - Electronic Components
  - Chemical
  - Biological
  - Computers
  - Software
- Second, those dual-use technology areas in which commercial and defense share leadership. These include:
  - Jet Engines
  - Satellites
  - Nuclear
- Third. those technology areas which are not dual-use, but are peculiar to defense. These include:
  - Stealth
  - Submarines
  - Reactive Armor
  - Cannon Tubes

The examples presented are not complete or exhaustive, nor are they intended to be. Exhaustive lists tend to generate the belief that we can control detailed areas intelligently on a case by case basis. What is needed, instead, is an easily understood policy that both protects what we need to protect while enabling global trade to flow freely to improve our economic situation and promotes global infrastructure to enhance long-term prospects for peace.

Before discussing the technology examples given, we need to understand the threats we are most likely to face. Once again, we cannot be certain that we will address every possible threat, but we can relate these threats to two of the four foundations of the National Military Strategy of the United States, published in January, 1992.

THE FOUNDATION OF U.S. DEFENSE STRATEGY

Strategic Deterrence and Defense

The receding threat of an all-out nuclear exchange between superpowers is being replaced by the threat of proliferation of weapons of mass destruction of property and/or life. These threats center on non-manned delivery vehicles (such as IRBM, ICBM, and cruise missiles) and their warheads (nuclear, biological, chemical, and conventional).

Thus, the technologies of central concern are those enabling and enhancing vehicles and warheads, and technologies which enable defense against such threats. These include, for example,

Solid State Electronics,

Software,

Exotic Materials,

Chemical,

Biological,

Nuclear.

Crisis Response

This is our second defense foundation and could take two forms.

MEDIUM-SCALE COOPERATIVE ENGAGEMENTS

Here, medium-scale means something less than a Persian Gulf engagement, as it is unlikely the United States will be able to commit such resources in the future. Such an engagement would feature existing air, ground, and sea weapon systems and their upgraded and modernized derivatives.

The technologies most important to this threat scenario are:

Solid State Electronics

Software

Computers

Exotic Materials

These technologies are the ones most likely to upgrade existing weapon systems.

UNILATERAL SMALL SCALE ACTION

Here the weapons scenario would shift more toward unmanned strike vehicles—the objective being surgical strikes without the risk of American lives—in an attempt to bring swirl resolution to the problem. Such an action would be technology dominated. Those most important would be:

Solid State Devices

Software

Computers

Exotic Materials

Forward presence and reconstitution are the remaining two foundations of our defense policy. Reconstitution, in a technological sense, has more to do with how to preserve and improve manufacturing and engineering processes central to threat profiles larger than those anticipated in this paper. Forward presence is covered in the medium scale and small scale actions considered above.

We can now start to make some overall observation about which dual-use technologies are critical to defense. Included in our list are:

1. Solid State Devices
2. Computers
3. Software
4. Electronic Components
5. Chemical
6. Biological
7. Exotic Materials
8. Jet Engines
9. Nuclear.

It is the author's contention that technological leadership is

- dominated by the commercial sector for 1-6;
- shared between defense and commercial sectors for 7-9.

As the author has more experience with the first four technologies, these will be used to explain the fundamentals which cause commercial leadership in them.

First, all four are dominated by use in global scale products or processes, such as television, appliances, games, and automobiles. It is necessary to amortize technology expense on a broad base to remain competitive. The defense industry, even in the United States, simply does not have the demand to support independent defense technologies in these areas.

Second, leadership is clearly commercial:

- Software operating systems are now commercially dominated.
- Solid state material and manufacturing processes must enjoy commercial scale to provide cost/yield effectiveness. The U.S. government dictates defense solid state processes must be founded on a commercial process.
- Computer chip sets must be commercially based to match operating systems and manufacturing (solid state) processes.
- Other than specialty items, there is little defense electronic component capability in the United States

The areas where technology leadership is produced by both the commercial and defense sectors present unique difficulties.

In jet engines, for example, those areas impacted by threat and speed have historically come from the defense sector. Those areas impacted by efficiency and life have historically been impacted by the commercial sector. With fewer engine requirements in the military, the drift is toward the commercial sector, although this technology, unlike computers and electronics, is relatively long-lived.

THE U.S. DEFENSE INDUSTRIAL BASE

As additional background, the nature of the U.S. defense industry must be discussed. Understanding its organization, attitudes, and how it does research and development helps to understand how technology improvement occurs, and the impact of dual-use control schemes on various companies.

There are three forms of suppliers to the U.S. Department of Defense.

Pure Defense Companies

These companies, in the main, do only defense business. Examples are Lockheed, General Dynamics and E-Systems. They reflect their customer (the Department of Defense) in organizational structure, and their research and development is funded solely by IRAD funds which are negotiated with the government (usually on an annual basis). These funds are partly profit and partly allowable costs of doing business. For any given company, their range is relatively limited (vs. that of a commercial counterpart) and speaks to the unlikeliness of defense technology breakthroughs driven by IRAD funds alone.

Nevertheless, these firms provide significant advantages over government arsenals because they are subject to a competitive environment and operate free from direct control of the government bureaucracy.

Companies Engaged in Both Commercial and Defense Work

Examples here are General Electric (GE), Westinghouse and Pratt and Whitney. Using GE as an example serves to illustrate various forms which exist here (GE regularly ranks in the top five defense contractors). The first thing to notice is that, by and large, the defense business is physically isolated from the commercial business. This is stimulated by bureaucratic regulation, perceived inefficiencies, and just plain differences in product. Notable exceptions are satellites and jet engines, where commercial and defense are physically collocated in the same buildings (while being organizationally and project isolated). Nevertheless, in these few instances there will be person-to-person transfer of technology unless a scheme is in place to guard against it (GE has one). Finally, GE's central research lab is organized to split defense work separately, primarily to ensure compliance with federal financial reporting regulation.

Companies Which Supply Commercial Off the Shelf Products to DOD

In general, these companies accept no DOD research money and supply products on an off-the-shelf basis. Nevertheless, there are federal regulations which require that all prices to the government be no more than that given to the best commercial customer.

The CIS should not be misled by general media insinuation of a military industrial complex. The current relationship between defense industry suppliers and the government is at a peak of contentiousness, and can best be described as a "love-hate" situation.

Overlaying this structure of companies is an environment of competition which was formalized in the Competition in Contracting Act of 1985. Our government has not yet decided upon the implications of a much lower defense budget, which undoubtedly will create a less competitive environment.

Now having discussed the most likely threats, the critical technologies needed to defend against those threats, and the fundamental structure of the U.S. defense industry, we can turn to some ideas on control of dual-use technologies.

Before making specific recommendations, the author wishes to express some deep-seated convictions in this matter.

- There can be no control over these matters without some form of anti-proliferation treaty which includes retaliation against offenders.

- Proliferation of the enabling technologies will happen—or they will be replaced with technologies which ripen in the commercial sector. A fundamental choice for the United States is to weigh strict technology controls vs. the debilitating impact this will have on our commercial global trade position. Choosing is a difficult judgment call. But, if we recognize both global peace as our long-term objective—and the inevitability of technology transfer, then the strongest position we can take is to: enable a dominant U.S. position in world trade; be the leader in an anti-proliferation treaty (that has retaliatory measures); and slow the transfer of the technology as applied to defense systems, enabling U.S. technological long-term leadership in these areas.

My recommendations and supporting discussion are as follows:

1. Control the technology application as reduced to practice in defense. Use security classification systems as the means of information and export control.

   - This results in controlling the export of the application of the technology.
   - The time cycle of application of technology in defense is longer than the cycle time of new technology.
   - Security systems are in place and, by and large, work.
   - Without the Department of Defense as the leading provider of technology—it is the application of commercial technology which matters.
   - allow an "out" for those few cases of export of defense technology in a commercial product (e.g., satellites) by specific application to an oversight board (not just DOD).

2. Dismantle COCOM and Replace it with a Treaty with Retaliatory Measures Specified.

   - We must accept that we cannot control proliferation by bureaucratic means, nor slow the pace of commercial technology around the world.

3. Continue Strict Controls on the Resale of Previously Developed Weapons and Systems to Third Party Countries.

   - No sale should be made without agreement on accountability of those systems supplied, including spares. In some cases this may cause the loss of a sale by U.S. companies. We should be prepared to stand by the basic principle of accountability.

THE JUSTIFICATION FOR ESTABLISHING IN RUSSIA A COMMISSION ON NON-PROLIFERATION OF POTENTIALLY STRATEGICALLY DANGEROUS TECHNOLOGIES

General Oleg K. Rogozin (retired)
Principal Research Scientist, RAS Elorma Program
Former Deputy Chief of Procurement, Soviet Ministry of Defense

There are very few specialists involved with problems of international security who doubt that strategic nuclear forces are the main culprit of an almost half-century lull in military conflict on the global level. This is an objective truth, most deeply realized during the Caribbean crisis of 1962, since this "genie released from the bottle" can bring a world catastrophe in an hour without victors and vanquished. After they came to believe in the security that nuclear weapons provide in their own arsenals, the superpowers (the United States and USSR) made not only each other a nuclear hostage, but even life on Earth itself. However, the dialectics of universal development are such that more and more countries are joining or trying to join the "nuclear club." Great Britain, France, and China have been members of this club for a long time; later India, Israel, South Africa, and Pakistan also developed nuclear weapons. This proliferation of nuclear weapons became one of the main motivations for the superpowers to pursue the process of gradually limiting and reducing them. Nuclear weapons are presently considered not only as a strategic means of aggression and retaliation, but also as a means to trigger possible war7s and military conflicts through their unpremeditated (because of technical reasons) or provocative use.

Theoretically (since it is not included in any official military doctrine), nuclear weapons also present a terrible ecological threat if, for example, some nuclear state suddenly decides to blast all its nuclear explosive devices. In essence, any sufficiently powerful nuclear explosion automatically and inevitably strikes at all of mankind, including those who initiated the nuclear strike. It is therefore very important to transform the current "model" ban on the use of nuclear weapons into an absolute political, moral, and military imperative.

Such critical opinions about the dangers of nuclear weapons are mentioned here only to dispel the illusions of imaginary safety resulting from strict compliance with provisions of signed treaties on limiting and reducing nuclear weapons. The world community, if it is really concerned about its future, should decisively move from a multitude of declarations on universal disarmament and endless steps of cuts of nuclear weapons to strict legal measures, maybe even forceful measures of self-defense against the nuclear Apocalypse.

Recent military-political developments and trends in the proliferation of nuclear weapons suggest a growing nuclear threat to the world community from several Islamic countries in the Middle East and in South-East Asia. One has to consider the possibility of the formation of new military blocs in these world regions that could be integrated with the Islamic states of the former USSR. Moved not only by their geostrategic interests, but also by their religious-fanatical motives, these blocks may become extremely dangerous to the southern regions of Russia. The commonality of their social-historical, national, and religious characteristics, and the one-dimensional socio-political structure of the states in the Middle East and the Islamic states of the former USSR, are worrisome to the West European countries and United States. This creates favorable conditions for cooperation with Russia and other Slavic countries in military-political, strategic and scientific areas. It is pertinent to note that United States and its NATO partners are worried not so much about the possibility of proliferation of strategic weapons to potentially dangerous countries (which can be controlled by national technical measures and covert intelligence), but by "brain drain" from the former USSR. These apprehensions further increase the necessity of a radical review of previous agreements on nuclear issues. From these circumstances quite naturally grows the number of UN members who support strict adherence to the provisions of the treaty on non-proliferation of nuclear weapons and who suppose that it should resolve the following problems:

- to establish a barrier to proliferation of nuclear weapons in other countries;
- to promote a reduction of nuclear and conventional weapons;
- to safeguard peace-loving countries from international nuclear terrorism and blackmail;
- to widen peaceful nuclear cooperation between states.

The Treaty on Non-Proliferation of Nuclear Weapons was approved by the UN General Assembly in June 1968 and entered into force March 5, 1970. It was signed by the United States, USSR, Great Britain, France, and 49 other states. By the end of 1988 the number of such states reached 186. Certain states, however, declined to sign it and covertly or overtly are trying to develop nuclear weapons. This means that the treaty is not specific enough; it is too declarative and liberal, although it contains political, legal, economic, logistical-technical and other assurances on the global, regional and national levels. Specifically, these assurances include monitoring based on the International Atomic Energy Agency (IAEA) agreements on the principles of nuclear exports, on rendering mutual technical assistance, and consultations on problems of peaceful nuclear use. At the same time, the physical commonness of peaceful and military nuclear technologies harbors obvious dangers and requires a more precise definition of scientific, design, trade and military aspects of implementation of this treaty. This will allow the most advanced nuclear states (primarily the United States and Russia) to conduct a common purposeful policy of controlling the non-proliferation of nuclear technologies in potentially dangerous states, including states that did not sign the non-proliferation treaty. Without these measures the international policy to limit and reduce nuclear weapons becomes more and more meaningless, since some states with nuclear weapons reduce them, while others develop nuclear weapons or increase their nuclear arsenals.

The main attributes of nuclear weapons are their means of delivery (ballistic and aeroballistic missiles, cruise missiles, artillery shells, et al.). The rapid development of means of delivery is noticeable in many developing countries. In 1989 about 20 countries had ballistic missile carriers—the carrier that is the least vulnerable in flight as compared to all types of delivery vehicles. In recent years Egypt, Iraq, Iran, North Korea, Pakistan, and Saudi Arabia developed such missiles. Twelve countries currently developing them. This process is aided by the ill-advised policy of developed countries, including the former USSR, of increasing the number of types and sizes of carrier rockets, granting licenses for their production, providing scientific-technical consultations and support. Such cooperation not only caused dangerous strategic shifts in many regions of the world but also nudged several peace-loving countries to develop these kinds of weapons. A chain reaction took place in the world and things went so far that several countries (including Argentina and Brazil) themselves became exporters of ballistic missiles. The fact that some of the countries that export ballistic missiles ignore the signing of the nonproliferation treaty causes concern.

An attempt to slow down this process was made during a conference in Washington from September 22-23, 1988 (with the participation of Schultz and Shevardnadze), and was continued December 1-2 of the same year.

The decision of the G-7 countries (the United States, Great Britain, France, Japan, Canada, Germany and Italy) on non-proliferation and the reduction of missiles was accepted. A range of flight of not more than 300 kilometers with a payload weight not more than 500 kg was accepted as the main criterion of export limitations (guidance accuracy was not specified). These kinds of limitations, however, are not very effective for the security of the European countries which have evenly distributed, highly integrated economies that contain many highly vulnerable installations (nuclear power stations, chemical plants, water-engineering systems, dams, etc.), although they are quite adequate for the United States, considering its remoteness from possible "hot spots" of the world. It would also be incorrect to consider such missiles as carriers of only nuclear weapons, since, in the hands of an aggressor, these missiles armed with conventional weapons may become a formidable factor of war or international terrorism. Such conventionally armed missiles present a strategically dangerous measure of political-psychological influence between countries. Therefore, strategically dangerous weapons cannot be limited to just nuclear weapons and other weapons of mass destruction (chemical and bacteriological warfare, radio frequency weaponry), since, in view of the high vulnerability of modem industrial installations, any high-precision long-range conventional weapon can be rightfully considered extremely dangerous.

Because of this, it would be beneficial for Russia to present to the Western countries an initiative to develop more precise definitions of the types, characteristics and features of strategically dangerous armaments, as well as a list of "key" technologies used in their production, including "dual-use" technologies, which should not be exported to the third-world countries. It would be advisable to entrust the development of such lists and the verification of accepted agreements among the Western countries to the Coordinating Committee for Multilateral Export Control (COCOM) and to an analogous Commission in Russia. The collective activities of these two entities should be extremely open and trusting, which would not affect the defensive capabilities of Russia, since it has a similar or slightly lower scientific and technical potential in the area of developing strategic weapons.

The Commission on Non-Proliferation of Potentially Strategically Dangerous Technologies (to use one possible names of this Commission) would synthesize military-political, strategic, military-technical, and legal information related to this issue. Its scientific nature, importance, and complexity of its activity, as well as its legal status, make it advisable and possible to establish such a commission in the Russian Academy of Sciences under the aegis of the Russian government. This Commission should include specialists of other existing commissions on related or similar problems

REQUIREMENTS FOR LEADING EXPERTS OF THE COMMISSIONS OF THE RUSSIAN CABINET OF MINISTERS ON CONTAINMENT OF POTENTIAL STRATEGICALLY DANGEROUS TECHNOLOGIES AND WEAPONS.

Physics	Nuclear physics, solid-state physics, radiophysics, optics, electronics.
Chemistry	Organic synthetic chemistry, technology materiology, technology of conversion.
Biology	Genetic engineering, toxicology, bacteriology, higher nervous activity, psychiatry.
Mathematics	Mathematical analysis, mathematical physics, game theory, cybernetics, informatics
Strategic armaments	Strategic nuclear weapons, strategic defense weapons.
Operatively-tactical armaments	High precision weapons, diversion equipment, weapons and personnel delivery systems.
Non-conventional armaments	high energy radiation and radiotoxins, geophysical and meteorological influences.
Information reception and countermeasures.	Intelligence, communications, management, informational counteraction.
All-system analysis of technologies and organization of expert examinations.	Classification of knowledge and technologies, automated bases of data and knowledge, classification of armaments and military technologies.
All-system analysis of results of expert examinations and preparation of publications.	Military doctrine and security, economics of armaments and conversion, legal aspects of problems in Russia and the CIS, international law, ecology and protection of the environment

Doctor of Technical Sciences, Professor, Russian-American University V.I. Tsymbal

MAIN GOALS OF THE PROPOSED COMMISSIONS OF THE CABINET OF RUSSIAN MINISTERS ON THE CONTAINMENT OF POTENTIALLY STRATEGICALLY DANGEROUSTECHNOLOGIES AND WEAPONS

Professor Valery N. Spector
Vice President of the RAS Elorma Corporation

1. Development of recommendations for adapting a system of government decisions by Russian leadership regarding the creation and use of strategically dangerous technology, based on the analysis of current and stable tendencies in the geopolitical and military-strategic situation in the world.
2. Development of recommendations and conclusions in accordance with the drafts of international agreements regarding the sorting of technologies according to the level of their potential strategic danger, which would depend on the dynamics of the geostrategic situation.
3. Development of recommendations and conclusions in accordance with the drafts of international agreements regarding control of migrating scientists and specialists who carry information on potential strategically dangerous technologies.
4. Development of recommendations and conclusions, in accordance with the drafts of international agreements, on the following: the agreed upon policy in the area of dual-use technologies; technological indications which define the impossibility of military application (for dual-use technologies); the mechanism for international notification about the creation of new, potential strategically dangerous and destabilizing technologies; and the significance of military production, relative to the general levels of production manufactured through the use of dual-use technologies.
5. Development of recommendations and conclusions in accordance with the drafts of international agreements, regarding restrictive lists in international trade, the participation in the COCOM agreement, and the latter's reorientation toward mutual export restrictions.
6. Development of recommendations on the selection of optimal decisions that would guarantee a strategic balance and national security in Russia, and which would be within the bounds of the concept of "unacceptable damage to the potential aggressor."
7. Preparation of proposals, conducting talks and reaching conclusions on behalf of the Russian government regarding the refinancing of Third World countries' debts, with an agreed upon discount, for supplies of weapons, and military equipment and the

transfer of strategic technologies. This will provide for expenses incurred as a result of socioeconomic, military, technical, and structural problems, resulting from the reorganization of the Armed Forces of the former Soviet Union into a professional Russian Army.

8. Development of recommendations and conclusions in accordance with the drafts of agreements (within the bounds of the Commonwealth of Independent States), regarding Russian relationships and policy in the area of transfer of potential strategically dangerous technologies to other states within the Commonwealth.
9. Development of recommendations regarding the optimal selection of strategic technologies for equipping the professional Russian Army.
10. Development of recommendations and conclusions regarding the conception of nuclear disarmament, which would comprehensively include questions about nuclear arms and the means of their delivery, as well as the different types of weapons of mass destruction and high-precision weapons.
11. Analysis of ecological consequences that would result from the destruction of nuclear, biological, and chemical weapons, and a development of recommendations for conducting these activities.
12. Preparation of recommendations for reporting on the utilization and neutralization problems which arise during strategic and conventional weapons negotiation processes as a result of freeing up of military-technical resources.
13. Development of suggestions regarding the means of assuring global strategic security and stability at a scientific, technical, economic and legal level, as well as the means of blocking the creation, use, and distribution of potential globally dangerous technologies and actions.
14. Participation in international meetings, conferences and activities of international organizations and movements which control the distribution of potential strategically dangerous technologies and ecologically dangerous dual-use technologies, and which deal with questions of conversion and its consequences.
15. Implementation of current analytical conclusions which are assigned by the Russian government.

APPLICATION OF VERIFICATION TO DUAL-USE TECHNOLOGY EXPORT CONTROLSAND RELATED ISSUES

John R. Harvey, Ph.D.
Center for International Security and Arms Control
Stanford University

Notes of briefing given to joint meeting of the U.S. National Academy of Sciences/ Russian Academy of Sciences working group on dual-use technology export controls held in Washington on May 26-29, 1992

PURPOSE OF THIS SESSION

The original purpose of the session is to address issues related to item #9 of the Protocol of the Soviet-American Meeting on Dual-Use Technologies and Conversion (signed in Moscow 20 December 1991). Specifically, item #9 directs the working group to examine the:

> "Contribution of verification schemes and other control measures to the building of confidence among nations as to the application of dual-use technologies and the possibilities of reconversion."

Needless to say, there is a strong overlap of this issue with item #4 of the protocol, namely:

> "The feasibility and desirability of separating applied research activities for military purposes from applied research activities for civilian purposes involving dual-use technologies with emphasis on:

(a) technologies which are "choke points" for military systems, and
(b) practical aspects of implementation."

My thinking on these matters, however, has evolved to something somewhat broader than the original subject. Specifically, the trend in the U.S., and very likely in the former Soviet Union and the newly democratic states of Eastern Europe, will be towards either a closer coupling, or continued close coupling, of the commercial and military technology and industrial bases. As I will try to argue, this trend will make it much more difficult to isolate, via verifiable end use controls, confidence building measures, and associated instruments, the commercial from the military application of dual-use technologies.

SUMMARY OF POINTS TO BE COVERED

- The trend towards closer coupling of the commercial and defense tech bases in the U.S. and Russia.
- The current Department of Commerce approach to controlling export of dual-use items including:

- products/commodities
- technologies to produce products and technical data
- human resources

- Issues in cooperative verification of end use controls
- An illustrative example

- MTCR high-leverage dual-use technologies
- Comments on the Russian sale of cryogenic liquid motors to India

TRENDS OF DEFENSE INDUSTRY

- DoD Budget has declined 35% since peak spending years of Reagan first term
- Major weapons system procurement has declined at a much more dramatic rate:

- $130B spent on procurement in 1985
- $50B projected for 1997

- DoD Science and Technology (S&T) funding has been level so far, but:

- overall budgets are declining
- as procurements decline, defense contractor IR&D will correspondingly decline so that total S&T investment will decrease

- To maintain excellence in defense technology in the current budget climate, DoD strategy must emphasize greater efficiency in defense R&D. Figures 1 and 2, and tables 1 and 2 illustrate some of these points. This will include:

- significantly decreasing, if not eliminating, the use of milspecs
- relaxing requirements for companies regarding technical data rights
- reducing onerous auditing and accounting requirements on contractors

- But, most importantly, DoD must take advantage of the great overlap between key commercial technologies and military critical technologies. DoD must:

- exploit the commercial base for non-defense unique technologies
- focus its technology development on key defense-unique technologies.

- Thus, the U.S. approach will be to much closer coupling of the defense and commercial technology bases.
- In Russia the system is different: the defense technology and industrial base has worked and is dominant; the commercial base, in many cases an offshoot of the defense base, has not succeeded in any measure in producing affordable and quality consumer goods for the Russian people.
- As Russia moves to convert (in effect transforming its military technology and industrial bases to commercial use) it has stated that it will use arms sales as a mechanism to finance this process. It, therefore, is likely to maintain or even strengthen the close coupling between defense and commercial technology bases.
- **This tight coupling is in the exact opposite direction from what we would desire in promoting transfer of dual-use items and technologies to the East. Specifically, end use controls that try to isolate a dual-use item from exploitation by the military will be much less likely to succeed if the defense and commercial bases are one in the same or close to it**.

- **Verification will also be much more difficult**.

- We will have the same problem if advanced Third World states evolve in this way.

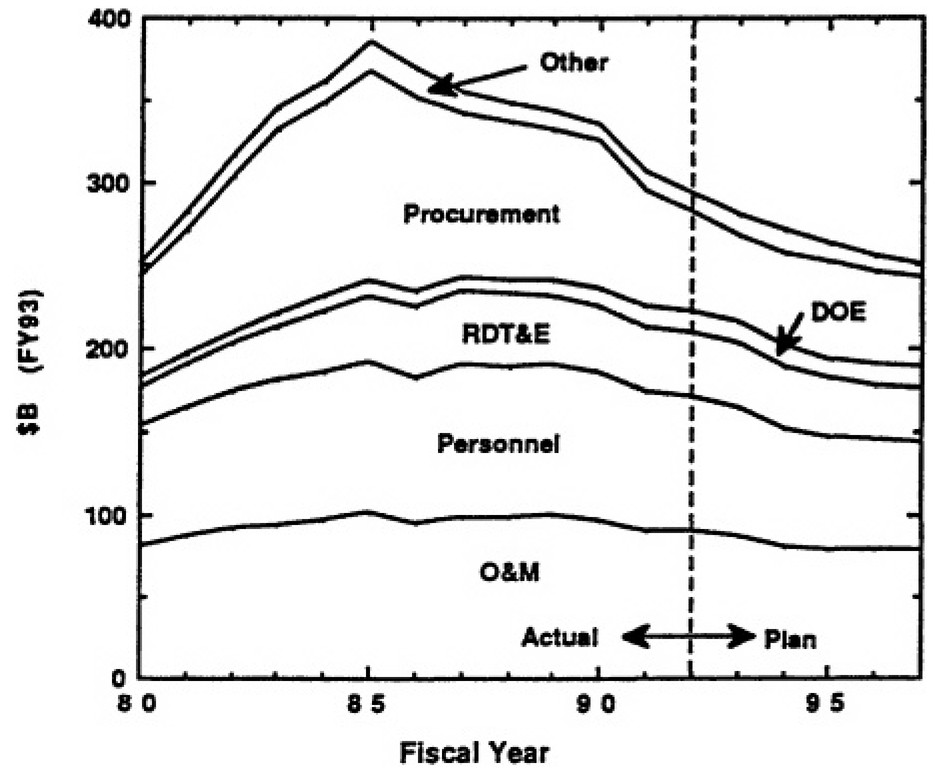


Figure 1 DoD 050 Budget Authority by Title (Bush FY 93-97 Plan)

Table 1—PRESIDENT BUSH'S NATIONAL DEFENSE FY 93 BUDGET REQUEST (35% REAL REDUCTION FY85 TO FY97)

Budget Authority	FY85	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97
Military Personnel	67.8	78.6	78.4	78.3	77.1	72.3	71.9	73.6	75.6
O & M	77.8	87.0	85.3	86.5	84.5	83.7	85.4	88.1	90.2
Procurement	96.8	81.4	66.5	58.5	54.4	58.6	63.3	61.5	63.1
RDT&E	31.3	36.5	36.1	36.9	38.8	39.7	37.9	36.8	36.0
Milcon	5.5	5.1	5.2	4.9	6.2	9.0	7.2	6.0	5.5
Family Housing	2.9	3.1	3.3	3.6	4.0	3.9	3.7	3.7	3.7
Other DoD	5.3	-0.1	2.3	3.1	3.9	1.7	1.5	1.9	1.7
DOE Defense	7.3	9.7	11.6	12.0	12.1	12.7	13.4	14.1	14.8
Total ($B then-year)	294.7	301.3	288.7	283.8	281.0	281.6	284.3	285.7	290.6
Total ($B FY93)	385.9	335.6	306.5	294.3	281.0	271.3	263.8	255.4	251.3
Real Decrease (%)	—	13.	21.	24.	27.	30.	32.	34.	35.

Notes:
1. "Real Decrease" is referenced to FY85.
2. Source: "Analysis of the FY93 Defense Budget Request," Defense Budget Project, March 11, 1992, Washington, D.C.

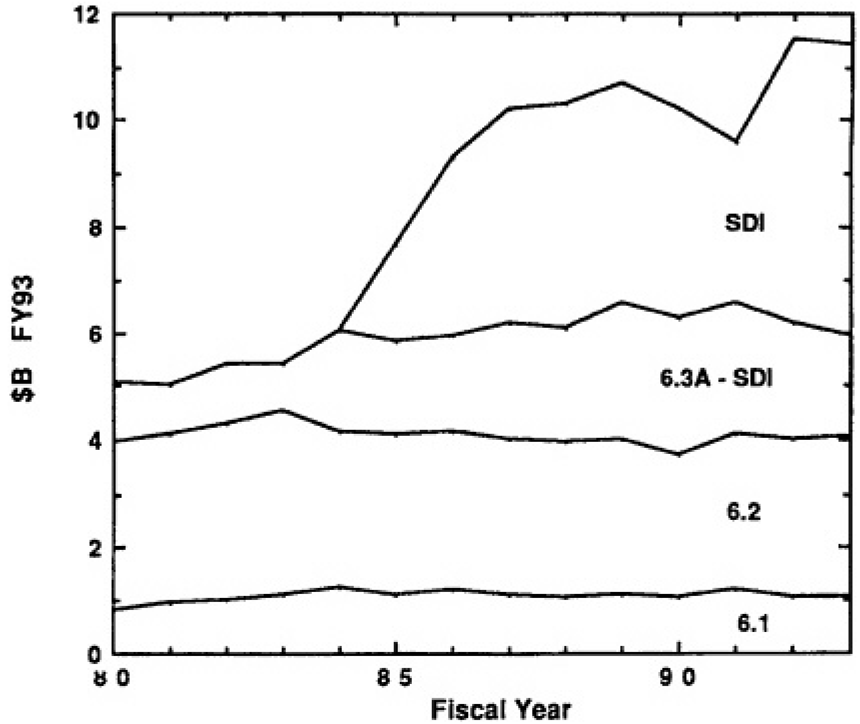


Figure 2 DoD Science and Technology Funding

Perhaps more important for U.S. maintenance of its technological "edge" in military capability is how spending on defense science and technology (i.e. the 6.1 basic research and 6.2 applied research programs, also called the defense technology base, and the 6.3A advanced technology development programs) will evolve in the future. If spending on the Strategic Defense Initiative (SDI) is excluded, these programs, constituting about 2% of the DOD budget, represent defense R&D that is not directed to a specific weapons system but which advances our understanding of, and experience with, key technologies that can lead to new defense capabilities.

As shown in Figure 2, when SDI is excluded, it may be seen that DOD science and technology funding has not shared in the defense spending increases of the early to mid-1980s. Indeed, the current 5-year projection suggests flat or slightly declining funding, in constant dollars, for these programs. When industry IR&D funds (which are tied to procurements) are counted, the prospects increase for significant overall reductions in defense R&D investment. The next chart shows the strong overlap between the national and DOD critical technologies lists.

Table 2—Critical Technologies Lists

National Critical Technologies List	DOD 1990 Critical Technologies List
Material Processing, Electronic and Photonic Materials, Microelectronic and Optoelectronics, Ceramics	Semiconductor Materials and Microelectronic Circuits, Photonics
Composites, High-performance Metals and Alloys	Composite Materials
	Superconductivity
Computer Simulation, Software, Data Storage	Simulation and Modeling, Software Producibility, Computational Fluid Dynamics, Data Fusion
Flexible Computer Integrated Manufacturing, Intelligent Processing Equipment	Machine Intelligence and Robotics
High-performance Computing, Networking	Parallel Computer Architectures
Systems Management Technology	
Sensors and Signal Processing	Passive Sensors, Signal Processing
High Definition Imaging and Displays	
Aeronautics	Air-Breathing Propulsion
Applied Molecular Biology, Medical Technology	Biotechnology Materials and Processes
Micro- and Nano-Fabrication	
Energy, Environmental and Transportation Technologies	
	Mostly Defense Unique Applications High Energy Density Materials Weapon System Environment Hypervelocity Projectiles Pulsed Power Sensitive Radars Signature Control

WHAT IS CURRENT COMMERCE DEPARTMENT APPROACH TO DUAL-USE EXPORT CONTROLS?

- First, what are the principal concerns about transfers of dual-use items (including products, technologies to produce products, technical data, and human resources) which have both military and civilian application?

- concern about diversion of an item to military program of recipient state
- concern about recipient state reshipping item to undesirable state

- How are dual-use exports currently controlled?

- Commerce has line responsibility, other agencies advise
- Commerce issues licenses (general and validated)

- Possible outcomes of Commerce Department action on particular license request:

- export prohibited to stated recipient
- export permitted without restriction
- export permitted with end use controls

- recipient identifies end use
- agrees not to divert or retransfer without authorization
- agrees to inspections

- Compliance assessment of end use controls involves:

- prelicense and post-shipment checks (may be random or routine)
- checks conducted by commercial attaches in embassy, Department of Commerce "flying squads"

- Enforcement involves sanctions and/or criminal penalties

- Commerce's enforcement function is woefully undermanned for what Congress has asked it to do

"NEW THINKING" ON DUAL-USE EXPORT CONTROLS: KEY ISSUES

- Which states are members of the "club" attempting to control technology transfer? Which countries would be the targets? The options for the members seem to be

- the United States and Russia
- COCOM and the former Warsaw Pact
- CSCE (but this excludes Japan, Taiwan, South Korea, PRC)
- UN (in this case both "members" and "targets" belong)

- As membership widens it becomes more and more difficult to agree on "targets."
- What are the goals of a regime?

- to prohibit direct transfers of high-leverage dual-use items to some states or entities within states
- to secure effectively verifiable end use guarantees against diversion, unauthorized retransfer
- to create confidence that obligations are being lived up to,
- are there other goals?

- How should the U.S., Western Europe and Japan "hedge its bets" against the remote possibility of a resurgent, militaristic neo-Soviet state arising from civil unrest in Russia and one or more of the new republics?

ISSUES ON VERIFICATION OF END USE CONTROLS

- What are criteria for verification?

- want to detect militarily significant diversion in sufficient time to react
- react means:

- mitigate effects of diversion
- redress any emerging instabilities resulting from diversion

- There will be limited resources for verification and control. This suggests that the export control regime prioritize the technologies of concern for specific states. E.g., (in order of decreasing priority):

- nuclear/chemical/biological of paramount concern
- dual-use technologies related to advanced delivery systems
- dual-use technologies related to PGMS,
- technologies related to other types of munitions

- It may also be useful to prioritize recipient states as to the level of concern regarding diversion. For example, if the U.S. were deciding (in order of increasing concern):

- U.S. allies
- benign neutral, non-aligned (NNA) (e.g. 'responsible' state, signed NPT/CWC/BWC, etc.)
- other NNA
- non-signers of NPT
- adversary of U.S. client or ally
- terrorist state
- adversary able to directly threaten U.S.

- But decisions on "targets" will most likely be multilateral. In any case, the pros and cons of the use of discriminatory policies directed against "countries of concern" should be addressed.
- In applying any policy, the issue of a country to absorb advanced technologies applicable to military systems (e.g., used in modification or reverse engineering of existing systems) should also be addressed.

- Other criteria for verification:

- will verification be cost effective
- will verification work? issues in this regard are:

- can key dual-use items be acquired elsewhere?
- how pervasive is the technology?
- are there large numbers of suppliers?

- will controls/verification degrade competitive advantage of U.S. firms?

- What are the <u>mechanisms</u> for verification?

- intelligence and NTM (e.g., could KGB and CIA cooperate?)
- cooperative measures among suppliers and between suppliers and recipients

- transparency and openness
- data exchange

- registry of weapons sales
- registry of transfers of dual-use items
- but, key question is how to avoid placing U.S. firms at competitive disadvantage

- inspections

- bilateral, between supplier and recipient
- multilateral
- target inspections on high-leverage items

EXAMPLES FROM THE MISSILE TECHNOLOGY CONTROL REGIME

The following five charts illustrate in more detail some of the previous discussion as it pertains to the MTCR. Specifically, in an earlier paper, we analyzed the ability of key proliferants for indigenous production of ballistic missile systems and associated technologies. The level of skill required was divided into four categories: (1) no indigenous capability, (2) the capability to modify existing systems obtained from abroad, (3) the capability to reverse engineer existing systems and (4) the ability to develop solid-propellant boosters along the lines of the U.S. ICBM program of the 1960s.

We found that many states of concern already possess the indigenous capabilities associated with points (2) and (3) above and, in ten years, many more could be at the level associated with point (4). Thus, export controls will have limited utility in restraining development in these states. On the other hand, some states have no indigenous capabilities and even if key technologies were provided they would be unable to absorb them in a missile program.

We did identify key missile-unique and dual-use technologies required for production and prioritized them. We found that human resources acquired from abroad was the single most helpful factor in providing states a capability for indigenous production.

An interesting example is the recent sale by Russia of cryogenic liquid motor systems and production technologies to India's space launch program. The U.S. has complained about the sale because of the commonality of liquid rocket motors for space launch and military systems, and imposed sanctions on Glavcosmos and the Indian missile research organization. Three items are noteworthy in this regard: (1) Gennadiy Burbulis, advisor to Yeltsin, called for close international supervision over the sale but this did little to reassure the U.S., (2) by providing hard currency to a Russian high-technology endeavor, the sale would advance two compelling U.S. foreign policy goals: it would have a positive effect on the chaotic Russian economy and it would reduce the incentives for key scientists and engineers to sell their skills elsewhere, and (3) U.S. cooperation with India in providing jet engines for India's light strike aircraft may actually play a larger role in increasing India's ability to deliver ordnance than any missile program.

Current Indigenous Production Capabilities

- No indigenous capabilities
- Libya, Syria, Saudi Arabia, Yemen
- Capability to modify Scud-like systems, little else
- Egypt, Iraq, Iran, Pakistan
- Capability to reverse engineer Scuds, make changes and produce solid propellant short-range missiles
- North and South Korea, South Africa?, Argentina, Brazil
- Advanced capability (near early-60s U.S. capability)
- India, Israel, Taiwan?

Indigenous Capabilities Ten Years in the Future

- No indigenous capabilities
- Libya, Syria, Saudi Arabia, Yemen
- Capability to modify Scud-like systems, little else
- Iraq?
- Capability to reverse engineer Scuds, make changes and produce solid propellant short-range missiles
- Egypt, Iran, Argentina, Pakistan?
- Advanced capability (near early-60s U.S. capability)
- Israel, India, Taiwan, North and South Korea, South Africa, Brazil

Summary of Controllability

- MTCR cannot prevent a number of states from acquiring ballistic missiles

- Scud-like missiles can be modified, reverse-engineered
- short-range, solid propellant systems are simple

- Simple controls on systems will restrain some states
- In some cases, qualitative improvements can be inhibited

- accuracy less than about 0.3% of range
- range greater than 1000 km

- Controls can decrease reliability and increase costs

Key Missile-Specific Resources and Technologies

- Experienced engineers, scientists, and technicians

- emphasize propulsion, G+C
- also management, systems integration

- Missile manufacturing facilities
- Complete missile systems and subsystems
- Missile guidance equipment; firmware and software
- Large solid propellant mixers (300 gallons and larger)
- Rocket motor test stands
- Cooperative missile development (e.g. SA-2 booster)

Dual-Use Technologies

- Space Launch Vehicles, components, and technologies
- Inertial Navigation Systems; gyroscopes and accelerometers
- Materials; e.g. carbon-carbon, polybutadienes
- Precision and Numerically Controlled Machining equipment
- Supercomputers and finite element codes
- Metal rolling and forging equipment

CRITICAL PROFESSIONS AND CATEGORIES OF SCIENTISTS AND ENGINEERS, PRINCIPLES OF THE PROFESSIONAL AND SOCIAL MOTIVATION OF THEIR ACTIVITIES, AND RATIONAL EMPLOYMENT UNDER CONDITIONS OF SCIENCE CONVERSION IN RUSSIA

Professor Yuriy N. Vershinin
Vice Chairman
Urals Division, Russian Academy of Sciences

First and foremost, it is pertinent to emphasize the major difference that has existed in position and status between the scientific workers of Russia and their counterparts in market economy countries. In terms of the planned-administrative economy that previously existed in Russia, the difference stems from the weak receptivity of civilian industrial sectors to scientific proposals, especially those which would lead to substantial changes in technology, let alone the creation of new technologies. The natural dissatisfaction of researchers with the existing state of affairs led to their striving to focus on theoretical and fundamental aspects of the technological problems involved. This is what accounts for the gap between the high level of basic research and the low level of the incorporation of these technologies in civilian industrial sectors.

A different situation emerged in the weapons-related industries. Global competition in the area of military production led the military industries to respond readily to achievements of science. A special system was even set up to search for scientific achievements to be used for military purposes. As a result, the highly educated scientific workers of universities and academic institutes readily tackled problems associated with sophisticated military equipment and weapons-related work or left their establishments to join scientific organizations of the military industrial complex. Other factors conducive to this process included better provision of such work with material and technical resources and scientific equipment, as well as a higher salary.

These circumstances need to be taken into account in analyzing the ways and means of converting science in the former Soviet Union to civil applications and in discussing the undesirable aspects of the "brain drain" problem.

One of the tasks crucial to conversion and to the promotion of mutual trust is the need to preclude the possibility of utilizing basic research results for the development of qualitatively novel military equipment and weapons. The experience of past decades has led to nuclear and chemical weapons receiving the most attention in this respect. The danger that these types of arms present when combined with modem delivery systems cannot be understated. At the same time, one cannot rule out the contingency that, in the depths of the various fields of fundamental science, arms can be devised that are based on new physical principles and on achievements of genetic engineering and biochemistry, and that meteorological and other types of weapons can be developed.

In this context, it is hardly possible to define the list of specialties of Russian and U.S. scientists and, accordingly, of research directions that could lead to results which would be dangerous to world stability. A more effective means to exclude such possibilities is to create a system of measures conducive to a greater openness and transparency of the research conducted by scientific communities and individual scientists in both the United States and Russia.

Reorienting (converting) a relevant part of the country's scientific potential to civilian applications thus calls for arranging a number of conditions that render this process most attractive to Russian scientists. These conditions include a number of possibilities for scientists:

- quickly implementing the scientists proposals and development projects in civilian industrial sectors and thereby improving their financial position,
- publication of papers and books in prestigious journals and by prestigious publishing companies to allow Russian scientists to gain international recognition;
- use of modem experimental research equipment;
- receiving a higher salary compared to that which scientists had when working for the military-industrial complex.

These opportunities should be realized in two stages:

- the first stage, a tactical one, calls for immediate solutions and comparatively limited material and financial resources;
- the second stage, a strategic one, is associated with large investments.

In either case, definite efforts are needed on the part of the legislative, governmental, and scientific structures of Russia and the United States.

Of fundamental importance here is to create mutual trust in governmental, industrial, commercial, and scientific structures and to overcome the stereotypes and styles that prevailed in the relations of our countries for many decades.

This applies primarily to dual-use technologies. To start with, it is imperative to define and to register legally the list of dual-use technologies that can be the subject of commercial operations between the countries of the Commonwealth of Independent States (CIS) and the United States. In the countries of the CIS, such a list is also needed in order to facilitate the procedure of transferring these achievements to civilian industrial sectors. Furthermore, there is every reason to believe that the effective use of relevant "American" technologies in the CIS is directly related to the necessity of exporting the corresponding technological equipment that is currently on COCOM's list. Thus, creating a list of dual-use technologies allowed for transfer to countries of the CIS is connected with an adequate reduction of the COCOM's list of equipment which assists the development of these technologies.

There is no doubt that such measures would help create an atmosphere of mutual trust in the industrial and governmental circles of our countries. It stands to reason that all this should be embraced by a monitoring system that precludes such technologies from being utilized for the creation and improvement of weapons.

Confidence-building measures and means of converting Russia's scientific potential coincide in many ways. All these measures are united by the need for openness and transparency of research programs and results to the world scientific community. The major method is by creating collaborative research programs and, accordingly, establishing joint groups of participants in research with the right to carry out individual stages of these programs, or the programs in their entirety, at scientific institutions in both Russia and the United States. This work would result in joint publications.

In our view, it is highly important that the corresponding foundations of both the U.S. and Russia be organized and used with due account to the features peculiar to the organization of science in Russia.

Members of the RAS are eminent scientists who work in the military industrial complex and in the universities of Russia. These structures possess the most complete and objective information about the scientific potential of both scientific teams and individual scientists. Also, they are least liable to bureaucratic diseases.

A Central Foundation Council should be established and its regional divisions should include representatives of the U.S. National Academy of Sciences and commercial organizations (as entrusted by the foundations). The main volume of work associated with the selection of proposals concerning collaborative activities or the choice of Russian partners for American scientific or commercial organizations should be effected in the regional branches and submitted to the Central Foundation Council for final approval. As experience is gained in work with Russian scientific, industrial, and commercial circles, these regional structures should become major centers of collaborative scientific and commercial initiatives.

The Central Foundation Council should comprise representatives of regional foundation divisions. Such an arrangement would help the council identify an objective solution and use the Foundation's means most effectively. Special treatment should be given to the problem of salary. This problem should be considered in accordance with Russian legislation. The following arrangements could be implemented: when Russian scientists carry out work on the territory of Russia, their work should be paid for in rubles and dollars (the dollar to ruble ratio is a separate issue). If that work is continued in the territory of the United States, salary should be in dollars. It should be borne in mind that the continuation of work in the United States may be connected with the necessity of confirming previously-obtained results on equipment that has the necessary assurances regarding calibration as specified in U.S. legislation.

To conclude, some brief comments must be made on the report "Reorientation of the Research Capability of the Former Soviet Union" presented by the U.S. National Academy of Sciences.

There is every reason to believe that the conclusions and recommendations of the workshop on this problem will receive support on the part of scientists working in various different institutes of Russia, including those in the military industrial complex. The major problem will consist in bringing these conclusions and recommendations to the attention of the governmental and legislative circles of both the Russian Federation and the republics and regions that are members of the Federation.

In doing so, one must to take into account the specific character of the distribution and organization of the scientific potential in Russia. A version that takes account of these peculiarities has been outlined above. The version proposed allows for the fact that proposals regarding scientific and commercial collaboration should be collected on regional levels, where Russian scientific and commercial potential is concentrated. This arrangement will be welcomed by local authorities and, in turn, can largely facilitate and considerably expedite the implementation of the proposals concerned. In this context, it is expedient to issue joint recommendations of Russian and U.S. scientists in Russian and in English and to submit them for publication to the central and regional governments of Russia.

The main point is that Russian scientists do not need a specific kind of humanitarian or financial assistance from the United States or other market economy countries. They are interested in realizing their scientific potential and technological results in carrying out collaborative scientific programs and fulfilling orders of firms. The problem resides in creating an efficient mechanism by which such programs and orders can be formed and implemented.

CASE STUDIES

Dr. Seymour E. Goodman
Department of Management Information Systems
University of Arizona

THE NEED FOR CASE STUDIES

The fifth point of the Protocol proposing bilateral activities on the problems of dual-use technologies and conversion calls for in-depth discussions of "case studies of programs to develop and to apply dual-use technologies for civilian purposes which are also designed to limit diversion of such technologies to military applications." [1]

Since the development and analysis of case studies requires substantial time and effort, it is necessary that we start our discussions by seeking agreement on the reasons for pursuing such studies and on how we would expect to benefit from them. From our meetings in Russia in December 1992, it would seem that both sides at least tentatively agree

- that some dual-use technology and product transfer between the two countries is necessary and desirable for important economic and scientific reasons;
- that it is desirable to reconsider the Soviet-era assessments of the risks of trade in dual-use technologies with Russia and the other former republics of the former USSR, and that trade controls be adjusted accordingly if the risk assessments are revised;
- that it is necessary for both countries to work together to limit diversions of dual-use technologies for military applications by third countries.

Progress along these lines arguably will depend on both sides cooperating to

- reduce many of the uncertainties in American export control policies and practices so that the United States will become a more predictable and reliable partner in the trade and transfer of dual-use products and technologies;
- help build a new legal, institutional, and behavioral order in Russia that will be able to insure against diversions to the same degree that is acceptable for most other countries;

- develop a new set of relations between the United States and Russia that will enable them to work together to prevent and track undesirable diversions of dual-use products and technologies.

To these ends, case studies would hopefully serve at least three important complementary purposes:

1. as test beds, for ascertaining the feasibility of, and to work on solving the practical problems that will arise with, control mechanisms such as verification schemes;
2. to develop models, consolidating the knowledge and experience obtained from simple cases and other experience into prototypes or models for effective vehicles to promote the use of dual-use technologies for civil purposes while controlling military diversion (these models might eventually be explicitly packaged into licensing mechanisms and conditions.);
3. for confidence building, using a small number of relatively controlled and risk minimizing cases to help build experiences that will be necessary to increase the confidence of both sides in each other and in their prospects for working out longer term and more extensive relations.

These three purposes apply to Russian-American trade and technology transfer and to trade and technology transfer between either and third countries. Clearly, case studies also serve as vehicles for the analysis of problems and the implementation of solutions that arise under many of the other points listed in the December 1991 Protocol; in particular, to the points relating to confidence building (point 3 on openness in research, point 6. on industry reporting, and point 9. on control and verification measures). [l]

PROSPECTIVE TOPICS

If we agree that case studies would prove valuable, then the next step is to decide what to study. Some possibilities that immediately suggest themselves are case studies of one or more of the most important dual-use technology sectors, such as computers, advanced materials, or civil aircraft. A key question that might be examined sectorially or more generally is the extent to which the former Soviet defense industries can effectively convert or spin off civil enterprises that absorb imported dual-use technologies and yet insure against diversion to sister enterprises still in the weapons business. One can study the forms of past diversions, the effectiveness of organizations such as joint ventures to help prevent diversion and provide verification, technological "choke points" [1], and the technical and economic factors affecting the controllability of products. Some of this has been done before [2, 3, 4], and the prospects of cooperative Russian

American efforts greatly increase the expectation of more complete studies that might be constructively used as discussed above.

We should also consider a somewhat more general case study of the changing institutions and priorities in Russia. Much of the practice of U.S. export controls against the USSR was based on a model of the Soviet system in which great priority and authority were given to Soviet security agencies. Under this model, it was assumed that the KGB and military-industrial organizations could obtain access to any foreign technology or products on Soviet territory, and that Soviet civil enterprises were almost powerless to restrict this access. This model generated a lack of trust in the ability of the Soviet legal or administrative system to prevent diversion or other misuse of dual-use technologies, and was used to justify very conservative U.S. export control policies and practices. One particularly important consequence of this distrust was an export control policy that amounted to a form of de facto economic warfare against Soviet civil industry.

Today's Russia is not the same place the Soviet Union was a decade ago, and U.S. policy has changed in some fundamental ways. We now want the Russian civil economy to develop in ways that will support a more democratic and consumer oriented civil society. To this end, we recognize that large parts of the former Soviet defense industry must be converted or dismantled and replaced by modem and viable state and private civil enterprises. For this to happen a necessary, but by no means sufficient, condition is for more normalized technology transfer and trade relationships to develop between Russia and the rest of the world, and this will require modification of old export control policies. This, in turn, will require confidence on the part of the United States that the former Soviet model for priority and authority has been replaced by a legal and administrative system in Russia that can be trusted to protect civil technology acquisitions from diversion for military purposes.

Accordingly, it is necessary for us to learn more about the current and changing legal and administrative structures in Russia, and to obtain some experience with possible methods of export control in the context of this environment. We must study the extent to which civilian and military activities are tied together organizationally and financially. We have to develop a more up-to-date model of the internal situation in Russia and of how this affects questions of access to and diversion of dual-use technologies. This applies to both the import of foreign technologies and to the export of Russian or the re-export of foreign technologies to third countries. Ideally, we would eventually like to have enough confidence in the Russian civil authority to permit the United States. and the other COCOM countries to deal with Russia in the way they deal with most other countries. This is arguably the most important case study we might undertake. Such a study might be undertaken broadly, or as a small pilot exploratory study to obtain some initial experience and data from a particular industry.

Another possibility would be to consider a case study of an important verification mechanism, such as end-use controls [4, Appendix C]. These are controls to limit the misuse of products that are physically located on foreign territory. Several forms of misuse are possible:

- inspection and analysis with the intent to duplicate or find the weaknesses of the product.
- diversion-in-place; for example, the use of a supercomputer located in a weather research facility to run military-related applications.
- relocation and diversion; for example, the movement of an array processor from a scientific laboratory to a submarine.
- diversion of manufacturing capability; for example, the use of imported microelectronics manufacturing equipment to produce components to be used in weapons systems.

End-use controls are most effective when applied to so-called "high walls" products that can be located, traced, observed, or otherwise tracked on an individual basis in a protective environment [4, Appendix C]. Some examples of such products include large supercomputers and major pieces of semiconductor manufacturing equipment. They also tend to be most effective against misuses in the form of relocation and diversion. The effectiveness of end-use controls against other forms of misuse is strongly dependent on specific local conditions.

A case study of end-use controls would consider the full spectrum of specific kinds of end-use controls and the circumstances in which each would be most effective. It would also consider different means of administering such controls.

As a final example, we might consider a case study of possible joint mechanisms and institutions for export controls. A joint Russian-American commission would be established to look into questions and procedures that could be applied to the export of dual-use technologies from either to certain third countries. The focus of this case study would be to carefully examine the current practices in both countries for licensing and monitoring the export of dual-use technologies in order to find common ground for a joint control regime. The joint commission would analyze several instances of real exports and some diversions in detail.

HIGH PERFORMANCE COMPUTING

I would recommend that we attempt a broadly exploratory case study that would at least start to look into several of the topics sketched above, but with special emphasis on confidence building in multiple ways. To keep this pilot project manageable, we should try to obtain our initial experience and information from a fairly small, but very important, specific technological sector.

High performance computing (HPC), including both traditional and massively parallel supercomputers, would be an excellent candidate for such a case study. Given our interests in the control and conversion of dual-use technologies, this sector might be usefully extended to include large mainframes and high performance networks as well.

HPC has been an exceptionally important and visible technology sector with a long history in the export control arena. Applications span an extraordinary spectrum of scientific, industrial, and military uses. Many of the most difficult problems of the control and conversion of dual-use technologies are encapsulated in this small sector. Both the United States and the former Soviet Union have exported large computers. A good case study with a focus on HPC should attract considerable interest.

The study of HPC, and of supercomputers in particular, should be manageable for at least four reasons. First, as compared with most other industries, a relatively small number of facilities are engaged in the development and manufacture of such machines. Second, almost all of these facilities are in only three places: the United States, the former Soviet Union, and Japan. Third, this is a "high walls" technology with a fairly small number of large end products that can be tracked as individual units on a worldwide basis. Finally, HPC has been the object of both general and specific controls and control procedures which might be usefully reviewed with respect to transfer to Russia, and which may serve as "strawmen" for proactively trying to help create a new civil authority for the control of dual-use technology in Russia and for exploring some specifics of joint Russian-American control regimes.

A case study of HPC could serve as a vehicle for testing arrangements, developing models, and building confidence in at least the following ways:

Movement of Technical Specialists and "Brain Drain"

The number of facilities engaged in the development and production of large computers in Russia is small enough for us to do a semi-exhaustive survey of the post-USSR movement of technical specialists in this technology. We might also note that at least one promising model has been worked out to keep R&D groups in this technology together and working inside Russia for a U.S. company, i.e., the arrangement for the Babayan group at the Institute of Precise Mechanics and Computer Technology (ITMVT) in Moscow. This model and other forms of joint ventures should be studied carefully. We might also look into the movement and brain drain of technical specialists in the C^3 (command, control and communications) area who worked on military systems using high end computers.

Conversion and Confidence-Building

As stated in Glenn Schweitzer's paper, "A Conceptual Approach to Addressing Dual Use Technologies: A Framework for US-Russian Dialogue," "If enterprises are to change from military to civilian production, they must replace their previous dependence on defense contracts with new approaches to financing, marketing, and profitability. Unless such a transition is successful and clear to all, international suspicions will linger that conversion has not really taken place and that technologies continue to be used for [military-related purposes].... [There must be] persuasive economic [and technological] evidence that conversion activities are genuine and permanent." [6] Clearly, detailed studies of enterprises in the process of conversion are necessary. HPC development and production facilities in the former USSR have had a long history of functioning under the purview of various combinations of both the Academy and the military-industrial ministries. A prime example is ITMVT in Moscow, which is under the Academy, and has had a long history of developing large machines for manufacture under the Ministry of the Radio Industry, and which has dealt with hundreds of space, military, and military-industrial customers since its creation in the early 1950s (late 1940s if one counts its predecessor in Kiev). As such, development and production facilities for high end computers should be ideal for the purposes of our case study.

Diversions and Confidence-Building

From the U.S. perspective, the best kind of case study would be one in which the Russian side is willing to find out about and reveal how technology was diverted as a means to help build confidence on the U.S. side, and to aid in help devise legislation, procedures, and institutions that will help build a civil authority capable of preventing, exposing and punishing such diversions in the future. Diversions in the high end computing arena should be fairly easy to identify since they are likely to constitute a small number of very discrete cases. The Soviet-era structure of the VPK (Military-Industrial Commission) and the ministries under its purview (particularly Minradioprom, Minelektronprom, and Minpromsvyazi in the case of HPC) had much to do with the reality and perception of the likelihood and authority for diversion. Our case study of HPC would provide a useful vehicle for assessing the current state of that structure, the participation of the intelligence agencies, and the extent to which Russian enterprises have become less vulnerable to pressures to cooperate in various forms of diversion.

Verification and Monitoring Mechanisms [1,4,6]

Supercomputers are "high walls" products in that they are usually heavy and large, produced in small numbers, maintain internal audit trails of users, and require prolonged vendor support. As such, HPC systems are well suited for consideration for verification and monitoring mechanisms such as end-use controls. A particular form of end-use controls, the Supercomputer Safeguard Plan, is one of the few examples with some serious history of use. One might argue that if we cannot work out effective verification schemes for these products, then we are not likely to be able to work out schemes for many dual-use technologies of great consequence.

Controls to Third Countries

The "high walls" characteristics of large computer systems should make such products ideal for a pilot case study of how the two sides can work together on the export or re-export of dual-use technologies to third countries. We can start with a review of how both sides have controlled high end computers in the past, with special attention to how specific exports have been tracked abroad. Specific forms of cooperation for the future would be considered. It is worth noting that while most of the former Soviet HPC sector is located in Russia, some significant portions are in Armenia, Belarus, Estonia, and Ukraine, adding an important element to this aspect of our prospective case study.

These possibilities are by no means exhaustive. For example, the tremendous applicability of HPC to a broad spectrum of scientific and military problems could argue for a good case study of the problems of the separation of research for civilian and military purposes. In conclusion, the point to underscore is the prospective viability and manageability of HPC as a suitable case study for almost any purpose of interest to our joint undertaking with regard to dual-use technologies and conversion. In this vein, we also have the option for a flexible and extensible case study that might be started in a modest and limited way, and expanded as experience and funding are acquired.

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ECONOMIC INCENTIVES, CONVERSION, AND DUAL-USE TECHNOLOGIES: THE CASE OF RUSSIA

Clifford G. Gaddy
Research Associate
The Brookings Institution

The purpose of this paper is to present a framework for analyzing how policy regarding dual-use technologies in Russia may be affected by the present and future economic status of defense enterprises. What I am talking about includes what is loosely referred to as "conversion." In the case of today's Russia it goes beyond that to embrace concepts such as "commercialization," "marketization," and "privatization." But for present purposes let me use the word conversion for all of this.

Much is unclear right now regarding the future of the Russian military industry. Certainly, straightforward prediction is impossible. However, I believe that simple economic reasoning can help define a range of possibilities, or scenarios, for the future of individual firms. My goal is to elaborate a set of such possibilities, with the hope that they can be usefully kept in mind as one examines how the dual-use issue relates to each.

I would also like to comment on two important economic policy issues relating to conversion that have recently been announced in Russia. These are a new law on conversion and the current official policy on arms exports. The exports issue in particular is a delicate one, and what I say may be controversial. But I believe that it is so critical to our main topic of dual-use policy that without an open discussion of it, everything else becomes academic.

THE ECONOMIC PROBLEM

What is the economic problem facing Russian enterprises? Fundamentally, it is the same as the problem potentially facing every other firm in the world: customers no longer want their products. Or, to be more precise, their current customers do not want the products they are currently producing. To survive, the Russian defense firm must somehow act to change this situation. This necessity is the same as for any firm in the world in the same situation.

What choices for action does such a firm have? Most of the world lies outside its control, of course. But generally it can at least control its own behavior: it can change itself. The changes can be of two kinds: it can change what it produces, or it can change to whom it sells. Or it can change both. The choices can be diagrammed something like the following:

WHAT?	TO WHOM?
OLD PRODUCT	OLD CUSTOMERS
NEW PRODUCT	NEW CUSTOMERS

The diagram suggests four paths of adjustment. That is, either:

- the firm's old product continues to be sold to the same customers as before (which can be thought of as "zero adjustment");
- the old product is sold to new customers;
- a new product is developed for the old customers; or
- a new product is developed and sold to a new group of customers.

Now, of course, this is very simplistic. In reality, things are not so clear-cut. When does modification of an old product become a "new" product? When does narrowing or broadening of an existing market go so far as to define a new market? And so on.

So far, this is a general scheme for a genetic firm. Does it—can it—apply to a Russian defense enterprise? There are certainly many differences between the situation of an American automaker, say, which is suffering a sales slump, no matter how severe, and a Russian tank manufacturer which sees its orders virtually disappear overnight. For one thing, the reduction in demand for the Western firm was probably gradual. This means that a firm has some time to adjust. This is clearly an advantage.

An even bigger advantage for the Western firm is the existence of a competitive market. Suppose a capitalist firm experiences a rather sudden drop in demand for its product. How does it react? Unless demand for that product just vanished altogether, the drop in demand for the product of one firm shows up as increased demand for someone else's product. This means that the losing firm has a good chance to ascertain why the drop occurred. That winning firm's product was of better quality; it was less expensive; it was marketed better; there was better after-sales service. The losing firm can try to isolate the problem and adjust accordingly. This is usually the first approach: try to improve the product, make it more attractive, better marketed, modify it, reduce its price by cutting costs, specialize more in the target consumer groups, etc. Only if these relatively marginal changes seem to fall does a firm resort to more radical steps, such as re-directing the product line.

There is a fundamental principle involved. It is basically a kind of "Least Action Principle"—if you can accomplish your goal in several different ways, you will rationally try to do it in the way that involves least effort. For economists, this is an axiom. For a given payoff, firms—like all other economic agents—will make choices which minimize their costs (where costs are defined broadly to include not only the monetary costs of production and marketing, but also other so-called transaction costs, including even psychological costs).

THE RUSSIAN CASE

How does this apply to a Russian defense firm? The collapse in demand in defense industry here may seem to be so different in nature and in extent as to defy meaningful comparison with anything in the West. This is not a question of a "product" suffering from flaws, or a competing supplier who is doing things better. The product itself is wrong. Russia is not looking for a better missile or a better nuclear submarine. It does not want any more missiles or submarines at all. Hence, there is no chance of adjustment of the product to suit the former customer.

But this is jumping to conclusions. Let us rather test the relevance of the scheme by looking at each of the four possible options for adjustment in the case of a Russian defense firm:

Old Product—Old Customer

This would mean continuing to produce (roughly) the same kind of arms for the state (admittedly, now the Russian state rather than the Soviet state...). Is this a viable option? Yes, arms will be needed. With a population of 150 million, and armed forces of 1.5-2 million men for the rest of this decade, Russia will need arms. Even without the more advanced systems "based on new physical principles" called for by defense minister Grachev, merely maintaining these forces will provide orders for many Russian firms for years to come.

Old Product—New Customer

Military procurement inside Russia is being slashed, but some of that lost market might be replaced by the foreign market. I will say more later about the possibility of arms exports. Suffice it to say here that the option of selling the old product on a new market is very much alive for many Russian defense enterprises.

(Someone might object to my referring to foreign customers as "new." The export market is hardly a new one for Russia—the former Soviet Union was a massive arms exporter. I would counter with the recent comments of Mikhail Bazhanov, head of the Russian State Committee on Conversion: yes, the USSR exported arms. But the customers were chosen on ideological, not commercial grounds. The Soviet state sold the weapons on credit, and provided this credit itself—long-term, interest-free loans. In effect, says Bazhanov, "our state was buying weapons from itself' and giving them to client states.)

New Product—Old Customer

Could a defense plant convert to producing civilian goods, but still count on the Russian state as its buyer? As a matter of fact, this is the case right now for virtually all the civilian goods produced by defense plants in Russia, since very few wholesale and large retail firms have been formally privatized. I am thinking of a different arrangement, however. Even with full-scale privatization of Russian industry and trade, the state may remain a major customer for the former defense plants. The best example of how this could happen is the type of large-scale infrastructure contracts espoused by some people. This is, for instance, the gist of the new "industrial policy" advocated by deputy defense minister Andrey Kokoshin.

New Product—New Customer

This is what I would like to call "full conversion"—i.e., former military plants producing civilian goods for private households and firms. This is the most obvious thing we think of when we think of "conversion," and it is certainly possible.

Thus, Russian defense firms have good reason to consider all four options. Which choice will they make? The enterprises are very different; they have different preconditions. The relative attractiveness of each option will vary from firm to firm. Hence, their choices will differ, depending on how their prerequisites match up with opportunities. So we should expect to see a mix.

But even for the individual firm, the choice is not a choice among a set of static options. We must also realize that the relative attractiveness is itself a variable that firms can influence, by influencing policy. That means that actions taken, and effort (and money) expended to influence policy will be very important. Economists will tell you that any time there is a potential economic payoff to an action, then it becomes included in the range of possible options. It may, to put it bluntly, be more worthwhile to invest some resources in lobbying than in actually producing.

INFORMAL MECHANISMS

A second complicating element in predicting a firm's behavior is the possibility that it—or, more correctly, its managers—might choose to go outside the recognized choices, and creme their own opportunities. Such actions fall into the realm of the illegal, although I prefer to use the term "informal" activities because of the unclarity about what is and is not illegal.

Let me give a couple of examples of such informal mechanisms. These happen to apply not only to defense enterprises, but to all categories of firms in Russia today.

One common activity has been to sell (at home on free markets or abroad) raw materials or intermediate goods which have been purchased at lower-than-market state prices inside Russia. Officially, the goods were to have been used as inputs in production. Instead, they are sold for profit. In the past, defense firms have had privileged access to shortage goods and were thus in an excellent position to behave in this way. This type of operation only works in an environment of non-market (distorted) prices. The 1992 price reforms make this behavior less likely in the future.

Beginning in 1991 and into this year, a wave of so-called spontaneous privatization has swept Russia. One form of such spontaneous privatization resembles a crude form of asset-stripping. In a "reorganization" of the firm, a firm's assets are distributed among enterprise personnel at a nominal valuation and then capitalized at full market price in any of several different schemes.

A third, related, practice is that of spinning off small private enterprises from a large state enterprise. Assets, sometimes including valuable intellectual property, are transferred to the spin-off company, where all proceeds are considered the private property of those who founded the company. This practice of "picking the raisins from the pudding" can make a few former managers and employees quite well off, but the majority of the work force are left to fend for themselves inside an increasingly worthless shell of an enterprise.

The list of informal mechanisms could be continued, and probably could never be made exhaustive for the simple reason that as soon as one loophole is plugged, another will be found. The important thing is to recognize that although such behavior as I have described may seem reprehensible in many ways, it is natural. It is the natural inclination of an economic agent—in this case, the enterprise director—to follow the path of least resistance. And in the case of the defense enterprise, adaptation to the market in the sense of producing civilian goods for private customers on an open market is not the "path of least resistance," even in the face of initial commitment by the government to a policy of no subsidies and no bailouts. Full conversion is a tough path, perhaps the toughest, and there are lots of ways firms have available to try to avoid it.

Recognizing the real options that firms and their managers face is important for any policy which relates to economic behavior. Economic policies are chosen to induce certain types of results by providing specific incentives and disincentives. The policies always assume a range of choices on the part of agents. You want to encourage some paths and discourage others. But if you fail to recognize that agents see other choices than you, your policies may produce the wrong results.

RESEARCH TASKS

The conclusion we must draw is that there are potentially many ways for defense enterprises to react to the drastic cut in defense orders. In particular, there are many ways to avoid a "productive" conversion to market-oriented civil production. We are already seeing firms act in some of these ways. There are undoubtedly others that we do not know of, that haven't even been invented yet. The research task is to follow these. I am convinced that one indispensable component in this research is case studies—very detailed on-the-ground studies. Simply put, we need to identify who is doing what, and why? This is a general research task for those interested in conversion (and economic reform in general).

For the specific issue of dual-use technology policy, we begin with the knowledge above, and then ask how does each type of behavior affect the dual-use issue. We should raise questions such as: What are the types of enterprises that will continue to be defense contractors selling to the Russian government? What is an appropriate dual-use policy towards them? What sort of former defense firms can be engaged in various infrastructure projects that serve only civilian ends? What role does dual-use play for them? Then the sensitive issue: Which firms will export? What will they export? To whom? And so on.

The point I am making is that without this "map" of the former military-industrial complex, it is rather meaningless to state policy.

Finally, we should not forget the possibility of informal behavior—the choices not listed in the formal scheme. Part of this is the issue of evasion of rules and agreements—certainly an issue of relevance to dual-use technology transfers. From the economist's point of view, the task is to find out who is likely to evade regulations, and why?

RECENT POLICY ON CONVERSION

Two important policy measures relating to conversion have recently been adopted in Russia. One is the new law on conversion. The other concerns arms exports. Both of these policy measures directly affect the choices defense enterprises will face as they decide how to adapt for survival.

LAW ON CONVERSION

President Yeltsin signed the new "Law on Conversion of the Defense Industry in the Russian Federation" on March 20 (although it was not made public until April 27). The law has many flaws: it is contradictory, vague, and simply avoids all too many key points by saying that "details will be provided later" or that things will be subject, in an as-yet-unspecified manner, to the provisions of other legislation, existing or future.

Perhaps the biggest problem with the conversion law, however, is that it is not really a law on conversion. It is a law providing the framework, and the first steps, for a comprehensive defense-economic policy. The real conversion law is yet to come.

Ideally, one would like to have, first, a clear military doctrine, which implies which weapons the country needs. That would then be followed by a clear definition of how those weapons are to be obtained. In the Russian case, this means delineating the spheres of continued active military production and resolving the issue of "mobilization capacity," as well as deciding on public versus private ownership. The final step would be provisions relating to conversion of those plants eligible for conversion.

Realistically, we have what we have: a conversion law that came before it has been decided what to convert. In fact, the conversion law is a mixture of all these steps, with timetables for the others. As usual, we can expect policy to be formulated as we move along.

But these criticisms aside, it is worthwhile looking at what the law does say in light of the possible choices for defense firms outlined above. The Russian conversion law in fact confirms that the individual enterprise will be faced with all four options for its continued existence:

Continued Arms Production

Article 3 of the law discusses the state defense order, which will, of course, continue to exist. The law also stipulates [Art. 2, para. 4] that enterprises may contract with the government to maintain, at government expense, "mobilization capacity." Enabling legislation accompanying the conversion law specifies [point 5] that the basic principles of Russian military doctrine and a "list of directions of activity in the military-industrial complex which will not be subject to reduction" shall be submitted by March 31.

Arms Exports

An entire section [Arts. 9 and 10] of the law is devoted to foreign economic activity by defense enterprises. Full allowance is made for arms exports.

Industrial Policy Contracts

Article 2, paragraph 3 of the law speaks of plans to enlist former defense firms in "priority targeted state programs for socioeconomic development" [*prioritetnye gosudarstvennye tselevye programmy sotsial'no-ekonomicheskogo razvitiya*]. The enabling legislation calls for such programs (which it calls "top-priority state conversion programs" [*pervoocherednye gosudarstvennye programmy konversii*]) to be submitted for approval by June 30.

Production for the Commercial Civilian Market

This option is given the least attention in the law. A very modest tax break will be granted to enterprises undergoing conversion on their own [Art. 5, para. 5].

ARMS EXPORTS

Clearly, there is a big incentive for Russian arms manufacturers to try to sell their products on the international market for hard currency. It is truly the "path of least resistance" for many firms.

One of the most outspoken advocates of Russian arms exports has been Mikhail Maley, Yeltsin's counselor on conversion issues. Unlike many others who have in the past criticized the Gorbachev conversion programs for their failure to demilitarize the economy, Maley criticizes those programs for the fact that they destroyed Russia's military potential. The preferred approach, says Maley, is to expand production of (at least some) Russian arms and to export them (for at least a "transitional" period). To that end, he is urging Yeltsin and other Russian leaders to work to eliminate all "unfair" quotas and restrictions on the Russian arms trade.

Maley calls his approach "economic conversion"—a meaning that has nothing to do with military conversion, but rather conversion to the market. "Economic conversion means turning the military-industrial complex into an export sector for a transitional period," said Maley in *Nezavisimaya gazeta* [February 28, 1992, pp. 1-2].

Defense firms will no longer be subsidized—they will be "self-financing," as in the old Soviet jargon. They should follow their own economic self-interests, which Maley believes (probably correctly) is to export as much as possible at as low a price as is necessary to sell. Maley projects revenues of $5 billion a year from arms sales. This then is to be used for "military conversion," although many observers have pointed out that it is highly unlikely that firms which have been successful in earning dollars in a particular activity will be eager to abandon it.

Maley is being allowed to use one republic, Udmurtiya, as his test bed for this policy. The republic is all behind him, for understandable reasons: no less than 86 percent of its industry is defense-related! Maley has invited Arab nations and others to invest in Udmurtiya to help implement his policy.

Much could—and should—be said about the consequences of Russian defense industry staking its hopes on the international arms trade. Not least among these consequences is what it implies for policies regarding transfer of dual-use technologies from the West. In my remarks in this paper, I have tried to look at the economic incentives for military conversion facing the individual firm. However, what makes sense for the individual firm may not make sense for the nation as a whole, or even for other firms. One of the social (as opposed to firm-level) costs of a policy of large-scale arms exports will be political restrictions, including restrictions on the transfer of dual-use technologies, to the Russian economy. A clear statement of what those costs might be, and who would bear them, would be useful in the current Russian policy debate.

APPENDIX I

Participants and Agenda for the Third U.S. National Academy of Sciences-Russian Academy of Sciences Joint Meeting on Dual-Use Technologies December 12-20, 1992 Moscow

AMERICAN PARTICIPANTS

Dr. Roland Schmitt, President, Rensselaer Polytechnic Institute; former Vice President for Research and Development, General Electric; former Chair, National Science Board; former President, Industrial Research Institute (NAS Chair)

Dr. Alan Chynoweth, former Vice President for Applied Research, Bellcore; Member of Optoelectronic Devices Working Group

Lt. General Lincoln Faurer (retired), U.S. Air Force; former Director, National Security Agency

Dr. Seymour Goodman, Department of Management Information Systems, University of Arizona; Member of High Performance Computing Working Group

Dr. John Harvey, Center on International Security and Arms Control, Stanford University

Dr. Robert Sprague, Division Staff Engineer, Aircraft Engines, General Electric; Member of Structural Materials Working Group

Dr. Mitchel B. Wallerstein, Deputy Executive Officer, National Research Council

NAS Staff Assistant: Peter MacDonald, Program Specialist, Office for Central Europe and Eurasia, National Research Council

RUSSIAN PARTICIPANTS

Academician Gennadiy A. Mesyats, Vice President of the Russian Academy of Sciences (RAS) and Chairman of its Urals Division; Chairman, RAS Council on Export Control; Member of Russian Government Committee on Export Control (RAS Chair)

Academician Yuriy E. Nesterikhin, Kurchatov Institute; Member of Optoelectronic Devices Working Group

Dr. A.A. Ovchinnikov, RAS Institute of Chemical Physics, Director, Department of the Electronics of Organic Materials; Member of Structural Materials Working Group

General Oleg K. Rogozin (retired), Principal Research Scientist, RAS Elorma Program; former Deputy Chief of Procurement, USSR Ministry of Defense

Dr. I.D. Safronov, Director of Computational Mathematics, Arzamas 16; Member of High Performance Computing Working Group

Dr. Valery N. Spector, Director of RAS Group on Dual Use Technologies; Vice Chairman, RAS Institute of Chemical Physics

Dr. Yuriy N. Vershinin, Deputy Chairman of the RAS Urals Division

RAS Staff Assistant: Yuriy Shiyan, Chief Specialist, RAS Foreign Relations Department

OTHER EXPERTS AND OBSERVERS

Colonel I. Belyaev, Assistant to the Chairman of the Applied Problems Section, RAS Presidium

General A. Danilevich (reserves), Co-Director, RAS Elorma Program; Senior Research Fellow, Institute of Military History, Russian Ministry of Defense

Robert Clarke, Science Counselor, U.S. Embassy, Moscow

General I. Lebedev (reserves), Scientific Secretary, RAS Council on Export Control

Dr. V. Levin, Council Chairman, Russian Transputer Association

Dr. L. Pyatnitsky, Department Chair, RAS Institute of High Temperature Research

Dr. A. Sobolev, Department Chair, RAS Institute of Cybernetic Problems

Dr. V. Sobolev, Department Chair, RAS Institute of Crystallography

Mr. Glenn Schweitzer, Executive Director, International Science and Technology Center, Moscow

Captain A. Shurygin (reserves), Senior Research Fellow, RAS Elorma Group

Colonel V. Tsymbal (reserves), Professor, Russian-American University; Co-Director of the RAS Elorma Program

Peter Wolcott, Department of Management Information Systems, University of Arizona

Dr. Gennadiy A. Yarygin, Head of Division on Conversion, RAS Center for Program Research

AGENDATHIRD U.S. NATIONAL ACADEMY OF SCIENCES-RUSSIAN ACADEMY OF SCIENCES JOINT MEETING ON DUAL-USE TECHNOLOGIES DECEMBER 12-19, 1992 MOSCOW

Monday, December 14		
2:00	Arrive in Moscow	
Tuesday, December 15		
10:00	Opening Address	
	Gennadiy Mesyats, Russian Co-chair	
	Roland Schmitt, U.S. Co-chair	
	Presentations on Conceptual Problems of Dual-Use Technologies	
	10:20	Mitchel Wallerstein
	11:00	Oleg Rogozin
	11:40	A. Danilevich
	11:50	V. Tsymbal
	12:00	A. Shurygin
	12:10	Gennadiy Yarygin
	12:20	I. Lebedev
12:30	General Discussion	
1:30	Lunch	
1:00	Visit to Yakovlev Design Bureau, Moscow	
Wednesday, December 16		
10:00	Presentations of Results of Joint Research	
	Structural Materials	
	10:30	Robert Sprague
	10:55	A. Ovchinnikov
	11:20	V. Sobolev

	High Performance Computing	
	11:40	Seymour Goodman
	12:05	V. Levin
	Electro-optical Devices	
	12:30	Alan Chynoweth
	12:55	Yuri Nesterikhin
	1:20	A. Sobolev
2:00	Lunch	
3:00	Visit to Scientific Production Association "Composite", Kaliningrad section of Moscow	
11:00	Overnight train to St. Petersburg	
Thursday, December 17		
8:30	Arrival at Hotel Rossiya in St. Petersburg	
9:45	Breakfast	
10:45	Sightseeing Tour of St. Petersburg	
1:30	Lunch	
3:30	Visit to "Leninets" Design Bureau	
Friday, December 18		
8:30	Breakfast	
10:00	Meeting with St. Petersburg Section of Russian Academy of Sciences on Conversion and Export Controls	
1:00	Lunch	
11:00	Overnight train to Moscow	

Saturday, December 19

10:00	Wrap-up session of National Academy of Sciences/Russian Academy of Sciences Joint Program on Dual-Use Technologies
12:00	Final Briefings from Russian Ministry of Defense, et al.
2:30	RAS-hosted lunch at Moscow Scientists Club

Sunday, December 20

8:00	Departure from Moscow

APPENDIX II

Participants, Agenda, and Initial Framework for the Second U.S. National Academy of Sciences-Russian Academy of Sciences Joint Meeting on Dual-Use Technologies May 12-20, 1992 Washington, D.C.

RUSSIAN PARTICIPANTS

Academician Gennadiy A. Mesyats, Vice President of the Russian Academy of Sciences (RAS) and Chairman of its Urals Division; Chairman, RAS Council on Export Control (RAS Chair)

Dr. Aleksandr S. Malafeev, Director, Perm Scientific Research Technological Institute

General Oleg K. Rogozin (retired), Principal Research Scientist, RAS Institute of Chemical Physics; former Director, Russian-American University; former Deputy Chief of Procurement, USSR Ministry of Defense

Dr. Valery N. Spector, Vice Chairman, RAS Institute of Chemical Physics

General Remir F. Stepanov (retired), Head of Department, International Fund for Social and Economic Reform; former Director of Export Control, USSR

General Leonid A. Timashev (retired), International Fund for Conversion; Elorma Corporation Ltd. for the Russian Academy of Sciences; former Deputy Minister of Finance

Corresponding Member Yuriy N. Vershinin, Deputy Chairman of the RAS Urals Division

Dr. Gennadiy A. Yarygin, Head of Division of Advanced Technologies, RAS Center for Program Research

Mr. Andrey M. Moryakov, Deputy Chief, RAS Foreign Relations Department

AMERICAN PARTICIPANTS

Dr. Roland Schmitt, President, Rensselaer Polytechnic Institute (NAS Chair)

Mr. John Betti, former Under Secretary of Defense for Acquisition, U.S. Department of Defense

Dr. Gerald Epstein, International Security and Commerce Program, Office of Technology Assessment, United States Congress

Lt. General Lincoln Faurer (retired), U.S. Air Force, former Director, National Security Agency

Dr. Alexander Flax, Home Secretary, National Academy of Engineering

Dr. Clifford Gaddy, Foreign Policy Studies Program, Brookings Institution

Dr. Seymour Goodman, Department of Management Information Systems, University of Arizona

Ms. Khristine L. Hall, Esq., Program Director, Public Affairs Governmental Programs, IBM

Dr. John Harvey, Center for International Security and Arms Control, Stanford University

Dr. Harvey Nathanson, Chief Scientist, Applied Sciences & Electronic Systems Division, Science and Technology Center, Westinghouse Electric Company

Dr. Richard O'Brien, President, Coming USSR, Ltd.

Dr. John Rittenhouse, Senior Vice President for Technology Programs, General Electric Company

Mr. Glenn Schweitzer, Director, Office for Central Europe and Eurasia, National Research Council

Dr. Mitchel B. Wallerstein, Deputy Executive Officer, National Research Council

Dr. Albert Westwood, Vice President for Research and Technology, Martin Marietta Corporation

OTHER EXPERTS AND OBSERVERS

Harley Balzer, Director, Russian Area Studies Program, Georgetown University

Richard C. Barth, Director for International Economic Affairs, National Security Council, Executive Office of the President

Walter Earle, Director of COCOM Affairs, Defense Technical Security Administration, U.S. Department of Defense

Jo Husbands, Director, Committee on International Security and Arms Control, National Research Council

Norman D. Kass, Deputy Director, Licensing, Defense Technical Security Administration, U.S. Department of Defense

Masayuki Kondo, Industrial Economist, Industry Development Division, Industry and Energy Department, The World Bank

Garth R. MacKenzie, Manager, C^3 Engineering Development and Engineering Division, Westinghouse Electronic Systems Corporation

Richard B. Sheppard, Senior Advisor on Defense Conversion, U.S. Agency for International Development

David L. Schlechty, Director of Country Policy, Office of Technology and Policy Analysis, U.S. Department of Commerce

Robert A. Summers, Chief, Defense Program and Analysis Division, Bureau of Nonproliferation Policy, U.S. Arms Control and Disarmament Agency

John R. Thomas, Senior Assistant for Soviet Science and Technology, Technology Cooperation and Security, Defense Technical Security Administration, U.S. Department of Defense

AGENDA SECOND U.S. NATIONAL ACADEMY OF SCIENCES-RUSSIAN ACADEMY OF SCIENCES JOINT MEETING ON DUAL-USE TECHNOLOGIES MAY 12-20, 1992 WASHINGTON, D.C.

Tuesday, May 26	
9:00-12:00	COCOM and Export Controls
9:00	Opening Remarks
	Roland Schmitt, U.S. Co-chair
	Gennadiy Mesyats, Russian Co-chair
9:30	Presentation and discussion of concept papers
	General Rogozin and Valery Spector
	Glenn Schweitzer
11:00	Break
11:15	Presentation and discussion of paper on the economic aspects of the development and production of dual-use technologies
	Clifford Gaddy
12:00-1:00	Lunch
1:00-5:00	Committee Discussions in Board Room, NAS
1:00	Presentation and discussion of paper on technology related industrial reports
	General Remir Stepanov
2:00	Presentation and discussion of papers on categories of manpower having unique knowledge of weapons systems
	Alexander Flax Yuriy Vershinin
3:45	Break

4:00	Summation/discussion
Wednesday, May 27	
9:00-12:00	Committee Discussions in Board Room, NAS
9:00	Presentation and discussion of papers on the feasibility and desirability of separating military and civilian applied research activities
	John Rittenhouse
	Gennadiy Andreevich Yarygin
10:45	Break
11:00	Presentation and discussion of paper on current trends in export control in Russia
	General Remir Stepanov
12:00-1:00	Lunch
1:00-5:00	Committee Discussions and Conclusion in Board Room, NAS
1:00	Presentation and discussion of paper on case studies of programs for developing and applying dual-use technologies for civilian purposes which are also designed to limit diversion
	Seymour Goodman
1:45	Presentation and discussion of paper on contributions of verification schemes and other control measures to confidence building in regard to dual-use technologies
	John Harvey
2:30	Break
2:45	Summary of workshop
3:15	Discussion of near term projects

4:15	Plans and suggestions for fall program
Thursday, May 28	
Briefing Sessions and Site Visits for Russian Delegation	
9:00-10:30	COCOM and Export Control
9:00-9:45	Dr. Robert L. Price, Director, Office of COCOM Affairs, U.S. Department of State
9:45-10:30	William Clements, Director, Office of Technology and Policy Analysis, Export Administration, U.S. Department of Commerce
	Norman D. Kass, Deputy Director, Licensing, Defense Technical Security Administration, U.S. Department of Defense
10:30-12:00	U.S. Defense Conversion
	Lawrence Korb, The Brookings Institution
	Katherine Gillman, Office of Technology Assessment
	Joseph Cartwright, Senior Project Manager, Office of Economic Adjustment, U.S. Department of Defense
12:00-1:00	Lunch
1:00-5:00	Site Visit to IBM Facility in Manassas, Virginia

Friday, May 29

Briefings in NAS 250:

9:00-10:30	Technology Related Industrial Reporting in the United States
	Robert Tinari, Assistant Division Chief, Current Industrial Production, Industry Division, Bureau of the Census
	Jennifer Bond, Director, Science and Engineering Indicators Program, National Science Foundation
	John Gawalt, Analyst, Science and Engineering Activities Program, National Science Foundation
10:30-12:00	End Use Verification
	Anstruther Davidson, Senior Policy Advisor to the Assistant Secretary for Export Enforcement, U.S. Department of Commerce
	John Phillips, Los Alamos National Laboratory, IAEA nuclear safeguards and inspections in Iraq
12:00-1:00	Lunch
1:00-5:00	Site Visit to Westinghouse Electronic Systems Corporation, Baltimore, Maryland

INITIAL FRAMEWORK FOR CONSIDERING DUAL-USE TECHNOLOGIES

1. Introduction

A. Changing character of international relations and implications for defense strategies, development and control of dual-use technologies, and international cooperation in business and research. Need to consider many interrelated aspects of dual use technologies in responding to growing interest in greater reliance on transparency and less reliance on controls. New emphasis on proliferation concerns and East-West strategic confrontation lessens.

B. Objectives of interacademy cooperation in considering dual-use technologies including building confidence to enhance national security, clarifying opportunities which facilitate the Russian transition to a viable market economy, promoting mutual interests in commercial transactions, and contributing to international science and technology.

C. Use of methodology set forth below to clarify problems attendant to specific technologies which illustrate full dimensions of the problems. Emphasize the following questions: When are controls appropriate? What are the approaches for strict controls? What is the importance of conversion and commercialization of civilian science and technology? What are the practical aspects of conversion of military technologies?

2. Initial selection of dual-use technologies which illustrate the variety of opportunities and problems in building confidence and reducing risks of proliferation. Complimentary technologies, including process technologies, may be considered at a later date.

A. A component-level technology: electro-optical devices
B. A materials-level technology: structural materials
C. A systems-level technology: high performance computers

3. Identification of opportunities for cooperation that reduce the need for controls.

A. Increased glasnost attendant to cooperation
B. Joint research and development and sharing of results
C. International approaches through UN or other channels

4. Circumstances or technological applications that do not require controls or reduce the need for controls. (The following examples were raised in the discussions but none of them have been deeply examined. These and other suggestions will be considered.)

A. Civil applications with little or no possibility of diversion
B. Redeployment of technical manpower
C. Internationalization of technology
D. Obsolescence and/or commoditization of technology

5. Circumstances or technological applications that require a continuation of controls. (The following examples were raised in the discussions but none of them have been deeply examined. These and other suggestions will be considered.)

A. East-West security concerns (use; re-export)
B. North-South proliferation concerns
C. Choke point technologies, including process technologies
D. Other key technological know-how

6. Identification of processes for monitoring and/or control when necessary. (The following examples were raised in the discussions but none of them have been deeply examined. These and other suggestions will be considered.)

A. Different levels of intrusion for reporting and inspection B. Criteria for end-use verification and transparency
C. Implementation of end-use verification
D. Reporting and maintenance of data bases
E. Processes and mechanisms for avoiding "technological surprise"

7. Consideration of new institutional arrangements (The following examples were raised in the discussions but none of them have been deeply examined. These and other suggestions will be considered.)

A. Modified COCOM
B. U.S.-Russia Center (analytical or control center)
C. Programs to reorient Russian weapons scientists
D. UN regional technology transfer center in the CIS
E. New stimulus to joint ventures and other business alliances
F. International cooperation in science and technology
G. Joint data bases and expanded use of electronic communications

APPENDIX III

Participants and Protocol from the First U.S. National Academy of Sciences-Russian Academy of Sciences Exploratory Meeting on Dual-Use Technologies December 13-21, 1991 Moscow and Perm

AMERICAN PARTICIPANTS

General William Bums, Former Director, U.S. Arms Control and Disarmament Agency

Dr. Clifford Gaddy, Research Associate, Foreign Policy Studies Program, Brookings Institution

Dr. Seymour Goodman, Department of Management Information Systems, University of Arizona

Mr. Don McLaughlin, TRW Components International

Dr. Mitchel B. Wallerstein, Deputy Executive Officer, National Research Council

Mr. Glenn E. Schweitzer, Director, Office for Central Europe and Eurasia, National Research Council

RUSSIAN PARTICIPANTS

Professor Ye. Bugrov, Institute for World Economy and International Relations

Academician B. Bunkin, Director General, Almaz Conglomerate

K. Gonchar, Institute for World Economy and International Relations

G. Kochetkov, Institute of USA and Canada Studies

Academician Gennadiy A. Mesyats, Vice President of the Russian Academy of Sciences and Chairman of its Urals Division

General Oleg K. Rogozin (retired), Russian-American University

Professor Valery N. Spector, RAS Institute of Chemical Physics

Yuriy N. Vershinin, Deputy Vice President for RAS Urals Division

Professor Gennadiy A. Yarygin, Institute for Program Studies

AGENDA EXPLORATORY MEETING FOR U.S. NATIONAL ACADEMY OF SCIENCES-RUSSIAN ACADEMY OF SCIENCES JOINT PROGRAM ON DUAL-USE TECHNOLOGIES DECEMBER 15-21, 1991 MOSCOW, PERM, RUSSIA

Sunday, December 15

Visit to Mayor G.N. Ukarov of Kungur.

Monday, December 16

Visits to:

1) Mayor V.Y. Fil of Perm
2) A.S. Malafeyev, Director, Perm Scientific Research Technology Institute
3) V.K. Malmygin, General Director, Production Association "Perm Machine Building Factory of the October Revolution."

Tuesday, December 17

Visit to Yu. S. Klyachkin, Chairman, Perm Scientific Center of Russian Academy of Sciences.

Wednesday, December 18

First meeting of planning group. Presentations by G. Kochetkov, Gennadiy Yarygin, and Valery Spector.

Visit to V.M. Surikov, Deputy Director for Science, Central Scientific Research Machine Building Institute (space sciences control center with related facilities).

Thursday, December 19

Second meeting of planning group. Presentations by B.V. Bunkin, Yuriy N. Vershinin, and Oleg K. Rogozin.

Visit to E.I. Bronin, Chief Engineer, Almaz Industrial Complex (conversion of SA-10 production facilities).

Friday, December 20

Third meeting of planning group. Presentation by A. Kiselev.

Visit to A. Kiselev, General Manager, and A.V. Lebedev, Head of Foreign Economic Relations, Khrunichev Machine Building Enterprise (boosters and space stations).

Farewell banquet and signing of Protocol (see below).

Saturday, December 21

Departure from Moscow

PROTOCOL OF THE SOVIET-AMERICAN MEETING ON DUAL-USE TECHNOLOGIES AND CONVERSION

Having discussed the reports of the roundtable participants and having become acquainted with a number of defense plants actively participating in applying dual-use technologies and in a conversion process, the parties agreed on the desirability of further bilateral committee activities and on in-depth discussions of the following problems:

1. Conceptual framework for helping to ensure that there will not be unanticipated technological breakthroughs in non-nuclear fields that could significantly change the military relationships among nations;
2. Identification of those categories of technical manpower which have unique knowledge concerning significant weapon systems and which could serve as channels for transferring such knowledge internationally in a manner which would enable the recipient countries to develop or produce weapon systems which could change the military relationships among nations;
3. Encouraging openness in basic research on technologies which could eventually have both military and civilian applications, through dissemination of research findings, international cooperation, and other means on a mutually beneficial basis;
4. The feasibility and desirability of separating applied research activities for military purposes from applied research activities for civilian purposes involving dual-use technologies, with emphasis on:

a) technologies which are "choke points" for military systems; and
b) practical aspects of implementation;

5. Case studies of programs to develop and apply dual-use technologies for civilian purposes which are also designed to limit diversion of such technologies to military applications;
6. Regular reports by industrial enterprises engaged in high technology activities which could contribute to the confidence of other nations that civilian industrial activities are not being diverted to military purposes without the knowledge of other countries;
7. Economic aspects of the development and production of dual-use technologies;
8. Current trends in export control in the USSR, the U.S., and multilaterally;
9. Contributions of verification schemes and other control measures to the building of confidence among nations as to the applications of dual-use technologies and the possibilities of reconversion;

10. Joint preparation of lists of technologies as the basis for controlling as appropriate:

a) critical military technologies;
b) basic technologies with civilian applications; and
c) dual-use technologies.

Head of the American delegation

General W. Bums

Head of the Soviet delegation

Academician G. Mesyats

December 20, 1991 Moscow