23315

2068



Central Intelligence Agency

Washington, D.C. 20505

**Directorate of Intelligence**

25 April 1990

# Soviet Core Technology Needs from the West to Support Future Military Programs

Summary

*In the 1990s, the USSR will focus on creating a leaner, more sophisticated military structure. To achieve this structure, Moscow will need some key Western technologies and equipment. To satisfy short term needs, Moscow's preference is for "whole systems" (e.g., air traffic control, telecommunications systems) that would immediately benefit both military and civilian applications. For long term needs, however, the vast majority of Moscow's Western technology targets will be for "foundation technologies"--technologies which have a broad impact on weapons capabilities and industrial processes. Using a "clean sheet" approach to identifying Moscow's Western technology needs essential to supporting long term military modernization, we have identified five key foundation technologies. In descending order of priority they are: microelectronics production equipment; computers and computer peripherals; advanced manufacturing; telecommunications; and advanced materials. For each of these technologies the Soviets will need a number of specific types of equipment (shown in box on page 2), used mainly to manufacture advanced products for military systems.*

CIA SW 90-20024 M

*This memorandum was prepared by [redacted], Office of Scientific and Weapons Research. It contains information available as of 25 April 1990. Comments and questions may be directed to the Chief, [redacted] OSWR*

WARNING NOTICE:
INTELLIGENCE SOURCES
OR METHODS INVOLVED

SW M 90-20024
CL BY
DECL OADR
DER FROM

15

SECRET

## Soviet Core Technology Needs

**Microelectronics Production Equipment**
- Automatic test equipment
  - Logic circuit testers
  - Memory circuit testers
- Material deposition equipment
  - Plasma enhanced chemical vapor deposition
  - Metal-organic chemical vapor deposition
  - Molecular beam epitaxy
  - Chemical beam epitaxy
  - Electron cyclotron resonance deposition
  - Magnetically enhanced sputtering
- Computer aided design equipment
- Lithography equipment
  - Stepping mask aligners
  - Electron beam lithography
  - Ion beam lithography
  - X-ray lithography
- Single-crystal compound semiconductor growth equipment
  - High pressure Czochralski
  - Liquid encapsulated Czochralski
- Etching equipment
  - Reactive ion etchers
  - Reactive ion beam etchers
  - Electron cyclotron resonance etchers
  - Magnetically enhanced etchers
- Defect detection equipment
- Ion implantation equipment

**Computers and Peripherals**
- High performance computers
- Design technology and workstations
- Disk drives
- Manufacturing technology

**Advanced Manufacturing**
- Computer numerically controlled machine tools
  - High precision machine tools
  - Computer numerical controllers
- Precision turning machines
- High accuracy measuring equipment
- Flexible manufacturing systems
- Robotics

**Telecommunications**
- Fiber optics
- Repeaters
- Digital switches
- High data rate microwave

**Advanced Materials**
- Fiber and filamentary materials
- Composite structures manufacturing
  - Filament winding equipment
  - Tape-laying equipment
  - Interlacing equipment
- Hot isostatic presses

# Soviet Core Technology Needs from the West to Support Future Military Programs (U)

## Soviet Requirements for Foundation Technologies

[redacted]as chronicled persistent Soviet efforts to acquire Western technology—both through espionage and illegal trade—for use in Soviet weapons design, development, and production. These efforts, together with Soviet statements, have demonstrated a preeminent need for key foundation technologies which have a broad impact on weapons capabilities: microelectronics production equipment; computers and computer peripherals; advanced manufacturing; telecommunications; and advanced material:

Moscow seldom targets *commodities*[1] in large volume to support military projects. Most commodity acquisitions are one-of-a-kind acquisitions to support reverse-engineering, and therefore are not substantially affected by export controls. Furthermore, most commodities are not easily controlled due to their large volume production, widespread proliferation, and lack of follow-on support requirements. Moscow's greatest needs are for the *production* technologies[2] listed above—technologies which are characterized by equipment produced in relatively small volume, interaction between supplier and user, and follow-on support and spare parts. These foundation technologies are the key bottlenecks inhibiting Soviet progress in military-related production area:

If Moscow had free and open access to most commodities, Soviet military systems would benefit substantially only if Soviet military designers were willing to use these commodities directly in military systems. In the past, the USSR generally has resisted this practice with a few exceptions, such as the use of some Western microelectronic components in weapon prototypes and limited production. Even if more Western commodities were incorporated into Soviet weapons, the net result would be to create a Soviet military dependency upon the West until and unless Moscow were able to develop indigenous production capabilities. For the most part, access to commodities without their associated production technology would force Moscow to continue reverse-engineering efforts, institutionalizing a lag of several years between the level of Western state-of-the-art and Soviet capabilities

> *Core Needs Philosophy*
>
> This list of core Soviet needs for Western technology is *not* a proposed export control list. Rather, it is our assessment of the key technologies which, if acquired in large volume, would provide a long term indigenous capability to substantially advance Soviet military technology. We have excluded equipment and technology which is either within Soviet capabilities, freely available outside CoCom nations, or freely available despite CoCom controls due to inherent lack of "controllability." Therefore, the production equipment and performance parameters we have identified do not necessarily mirror the current CoCom list or the latest US CoCom proposal

[1] We define commodities as items which could be used directly in Soviet military systems, either as raw materials, subcomponents, subsystems, or the actual systems. Examples include steel, integrated circuits, turbine engines, and deep-ocean submersibles, respectively. In all such cases, the commodity is used up and must be replenished

[2] We define production technology as equipment or technology which could be used to design, develop, or produce advanced commodities for future military systems. Examples include computer numerically controlled machine tools and computer aided design systems. In all such cases, the equipment or tec[illegible] acts as a capital investment which can be reuse[illegible]

**Microelectronics Production Equipment**
Microelectronics is the key technology for Soviet military programs in the 1990s. It supports a wide variety of weapons applications, mostly focused on obtaining better performance from fewer weapon systems and more operations from smaller packages. This is a critical goal for Moscow as it reduces conventional force levels to allow more efficient economic development. Microelectronics will be the limiting factor involved in almost every future weapon system.

Soviet problems with obsolete production equipment, low-quality raw materials, and poor quality control severely limit their ability to produce high-performance, high-quality microelectronic devices. Using extensive technical guidance from leading industry experts, we have identified the production equipment which would have the greatest affect on the performance and reliability of Soviet integrated circuits, and have selected relevant performance parameters to separate equipment by ability to produce more advanced circuits. Unlike the current CoCom list, we have not included equipment or performance parameters which primarily affect production yield or throughput. The Soviets' most pressing microelectronics production technology needs are for:

- *Automatic test equipment.* Soviet deficiencies in manufacturing advanced automatic test equipment are directly related to their difficulties in manufacturing high-speed computers. Lack of this test equipment is felt most acutely on military specification integrated circuits (ICs), which must undergo 100 percent testing prior to use in systems. The types of testers most required by the USSR are logic circuit testers and memory circuit testers. The most important parameters for equipment to test logic circuits are time measurement equal to or less than 0.25 nanoseconds and pin count equal to or more than 128 pins, while the most important parameter for high speed (above 20 megahertz) equipment to test memory circuits is maximum memory address equal to or more than 256,000 bits.

- *Material deposition equipment.* Soviet IC fabrication is limited by difficulties in depositing uniform layers of various materials on the surface of the IC. These materials include oxides, nitrides, silicides, and metals and are used as insulators, conductors, or semiconductors.

  Soviet inability to deposit a thin oxide layer, for example, directly limits its operating speed to only one-third of typical Western speeds for that circuit. The types of deposition equipment most required by the USSR are: plasma enhanced chemical vapor deposition (PECVD); metal-organic chemical vapor deposition (MOCVD); molecular beam epitaxy (MBE); chemical beam epitaxy (CBE); electron cyclotron resonance (ECR) deposition; and magnetically enhanced sputtering. The single most important parameter for PECVD and ECR deposition is layer uniformity better than 1.5 percent. The single most important parameter for CBE is thickness control better than 20 percent. The single most important parameter for magnetically enhanced sputtering is uniformity better than 20 percent. There are no parameters for MOCVD or MBE to separate military from civilian applications; however, these technologies are used almost exclusively for advanced, compound semiconductor growth, which is primarily for military applications.

- *Computer aided design equipment.* Most advanced Soviet logic ICs—which involve complex circuit designs—are little more than copies of proven US ICs. The USSR lags badly in computer aided design (CAD) and computer aided engineering (CAE) equipment, which is typical for all types of computers. Soviet difficulties designing complex logic circuits limit their ability to produce both general purpose and application specific ICs for military uses. CAD/CAE equipment combine hardware and software to transform a theoretical circuit design into a physical circuit layout. The single most important parameter is the ability to store and process data representing more than 100,000 transistors.

- *Lithography equipment.* There is a common misconception that Soviet microelectronics capabilities are primarily limited by lithography problems. This is based upon mirror-imaging—assuming that the Soviets are limited by the same factors which limited the

West in producing comparable devices. On the contrary, [redacted] Soviet ICs has revealed good lithographic capabilities down to 2.5 micron linewidths. For most applications, standard mask proximity or contact optical lithography equipment available from East Germany is capable of transferring the circuit pattern onto the wafer. Some optical lithography equipment, particularly stepping mask aligners capable of production resolutions below 1.5 microns, are needed by the Soviets for advanced applications, most often military-related. Sophisticated non-optical lithography techniques (such as electron beam, ion beam, or x-ray lithography) are not now required for Soviet ICs, but are likely to be more important in the future as the need for miniaturization increases. The most important parameters for any of these systems are resolution better than 1.3 microns and overlay registration better than 0.3 microns.

- *Single-crystal compound semiconductor growth equipment.* Deficiencies in Soviet-produced crystal growth equipment specially suited to produce compound semiconductors limit Soviet ability to fabricate military circuits such as sensors or high-speed, radiation-hard ICs. The basic material for almost all current microelectronics production is silicon. Compound semiconductor materials--such as gallium arsenide--are more difficult to produce and to process into electronic devices, and therefore are primarily reserved for military applications. The types of compound semiconductor crystal growth equipment most required by the USSR are high pressure Czochralski systems and liquid encapsulated Czochralski systems. The most important parameter for these systems is etch pit density less than 10,000 per $cm^2$.

- *Etching equipment.* Although current Soviet etching capabilities are adequate for all currently-produced Soviet ICs, Soviet problems etching very fine lines with vertical walls will limit their ability to make advanced military-specification integrated circuits by the mid-1990s. The types of etching equipment most required by the USSR are reactive ion etchers, reactive ion beam etchers, electron cyclotron resonance etchers, and magnetically enhanced etchers. The most important parameter for these systems is uniformity equal to or better than 3 percent.

- *Defect detection equipment.* The Soviet microelectronics industry suffers from across-the-board problems with production quality control. This affects both production yield and IC reliability for advanced ICs. For military specification ICs in particular, quality control is extremely important. Defects can lead to early and unpredictable device failure. For example, in addition to the usual cause (alpha particles emitted from the IC package), state-of-the-art IC fabrication facilities have found that small dust particles in advanced memory ICs can also cause intermittent memory failures called "soft errors." To compensate for inferior IC quality and reliability, Soviet weapons designers must incorporate multiple redundancy into their designs. Defect detection equipment capable of finding both random and systematic errors would substantially benefit military IC quality. On the other hand, standard Soviet civilian ICs would not normally require individual defect detection to supplement normal electrical testing. The most important parameter for defect detection equipment is sensitivity equal to or better than 0.75 micron.

- *Ion implantation equipment.* Deficiencies in indigenous ion implantation equipment limit Soviet ability to implant deep impurity layers and to implant through a thick oxide layer in production ICs. This ability is important for some militarily-important device structures, such as silicon-on-insulator, which are radiation hard. The most important performance parameter for an ion implanter is beam energy, which governs how deep an average ion travels into the wafer. Moscow would benefit if high-energy implanters with accelerating voltage over 160 kilo-electron-volts were freely available

Beyond the 21 equipment types in the eight categories we have identified as the most important to improving the performance of advanced, military-related ICs, the Soviets have a number of other technology needs. In fact, we judge that Moscow is deficient to some extent in almost all major types of microelectronics production equipment. Most of these other equipment types primarily affect production yield but not device performance. As such, they probably fall lower on Moscow's priority list than do those which affect circuit performance

If Moscow were able to legally purchase any of the specific microelectronics production equipment types *not* identified above, the Soviet microelectronics industry could produce any consumer integrated circuit likely to be required for their *indigenous* consumer and civilian industrial demand. If the 21 microelectronics production equipment types identified above remain embargoed, the Soviet microelectronics industry would have difficulty producing advanced integrated circuits for future military applications. Moscow would also have difficulty producing advanced civilian integrated circuits able to compete in the *Western* market with Western state-of-the-art ICs. However, we judge that, even if Moscow had unrestricted access to the best Western production equipment, longstanding Soviet problems with an inefficient workforce, obsolete production facilities, and poor quality control will prevent the Soviet Union from competing effectively in the worldwide microelectronics market until well into the next century

*Key Military Applications of Microelectronics*

Microelectronics are key to almost all modern weapons capabilities; however, several important weapons applications stand out. The sophisticated signal processing used in passive sensors onboard stealth aircraft require advanced microelectronics. Microelectronic devices are key to advanced sensor applications applicable to anti-submarine warfare. And the complex problem of strategic defense depends largely upon advanced microelectronics as part of the solution to each major task, ranging from target discrimination to acquisition and kill.

**Computers and Peripherals**

The Soviet lag in computer development and production is adversely affecting both military and civilian computer applications. In military developments, the Soviets are avoiding complex multi-mission systems which require high-performance computers and disk drives. The impact is most important for those applications with intensive computational requirements and those needing large data bases. Soviet military leaders would particularly desire modern computer-aided design capabilities to improve the availability, reliability, and performance of weapon systems while reducing the human and material resource requirements

In the civilian arena, plans for industrial modernization rely heavily on modern computers that currently are unavailable. Lack of engineering workstations and high-speed computers will continue to stifle the productivity and creativity of Soviet scientist and engineers.[3] Workstations are needed to implement computer-aided technologies--such as CAD, computer-aided manufacturing (CAM), and computer-aided testing (CAT)--which are key elements in modernization of Soviet civilian as well as military industr

The Soviet computer industry is constrained in large part by gross deficiencies in the semiconductor industry. Until they can solve their serious IC problems, future advances in computer technology will depend on innovative logic designs using available ICs and on interconnect, packaging, and automated manufacturing and testing technologies and equipment. The Soviets' most pressing needs, therefore, in the computer and peripheral areas are for:

- *High-speed, high-capacity computers.* The lack of fast computers with large main memories and fast, high capacity disk drives directly affects Soviet weapon systems, such as command, control, communications and intelligence ($C^3I$) support, that depend on these computers in their actual operation. It indirectly affects other weapon systems, such as aircraft, that depend on these computers in their design and production phases. Strict export controls on high performance, general purpose

[3] We recognize that computer software is a core technology and is often the key element in the successful application of computers. The USSR is substantially behind the West in the design, development, use, and maintenance of complex, militarily-useful software. We do not believe, however, that export controls have been an effective means of controlling software--software companies have gone to great lengths to protect their programs for commercial reasons, usually unsuccessfully. Classification provides the best method of software protection

computers and supercomputers have precluded the Soviets from developing a supercomputer capability based on a Western system. Left to their own devices, the Soviets have been unable to achieve supercomputer performance using indigenous technology. Current Soviet research seems to be concentrated on achieving high speed through the use of parallel and other novel architectures. This approach allows the Soviets to shift the design burden from one of their weaknesses, design and production of sophisticated electronic devices, to one of their strengths, innovative mathematics and algorithm design. However, supercomputers are generally considered to be necessary for simulation and modeling of complex systems, such as hypersonic vehicles, for which test facilities are not available. The most important parameter for such computers is speed, usually expressed in megaflop performance based on benchmarks used to rate current supercomputers. In that context any system rated at a sustainable rate of 10 megaflops and above would be key to Soviet military needs.

➤ *Design technology and workstations.* We believe Soviet engineers will continue to depend on Western computers as their prime source of design direction. Reverse-engineering, however, will become increasingly difficult, requiring extensive adaptation and compromise to meet military performance requirements. In addition, the Soviets will need state-of-the-art CAD hardware and software from the West, including high-performance CAD workstations for logic design and verification, system simulation, wiring layout optimization, design of multilayer printed circuit boards, design of high-performance peripherals--particularly disk drives, and prototype system design. Workstation performance is best measured by a combination of processing data rate (PDR) and 3D vector rates. Here a PDR above 275 megabits per second along with a 3D vector rate above 100,000 per second would be most important.

➤ *Magnetic disk drives.* Low performance and inadequate production of disk drives is a major computer hardware deficiency facing the USSR, and is limiting the performance of their computer systems in many applications, including military. Their principal difficulties lie in the integration of a number of precision manufacturing technologies. Although the low performance of Soviet drives may impose only inconveniences for the majority of computers in use, system performance of current and future high-speed computers will be severely hampered without further advances in disk technology. Some military systems requiring the high-speed processing of large amounts of data most likely have been negated, delayed or reduced in capability because of disk drive deficiencies. In the case of disk drives as a part of a total system it is important to control total system performance rather than individual drive performance. For military utility of large systems the key parameter is total connected net capacity of about ten gigabytes and a total transfer rate of about 20 megabits per second. For workstations and other small systems that may incorporate disk drives, the important parameters for military utility are at about 500 megabytes and 10 megabits per second, respectively. The military utility of unlimited quantities of disk drives available to the USSR individually rather than as parts of systems, however, becomes important when the individual drives exceed about 200 megabytes in capacity and about 10 megabits per second transfer rate.

➤ *Automated manufacturing technology.* The Soviets will be seeking to increase the level of automation in design and manufacturing processes. Many of the Soviet computer production problems are a direct result of insufficient attention to manufacturability during the design process and poor workmanship during the manufacturing process. Automation will not only increase productivity, but will also increase the reliability of the product. Eventually, it will facilitate production of more advanced computers and peripherals. Both automated design and production equipment and technical know-how will be key targets in the West. Specific targets include:

- CAD workstations for disk drive design.
- Technology for manufacture of thin film heads.
- Oxide and binder coating technology.
- CAD hardware for multilayer boards.

- Technical know-how for dissipating heat in high-speed computers.
- Technology for surface mounting.
- Information on inspection and test procedures.
- Information on quality control.

Engineering workstations and the know-how in their assimilation will be important in improving the design phase in Soviet computer efforts. Key to Soviet improvements in quantity and quality of computer production is technology–technical data and know-how. Export controls, however, have proven to be virtually ineffective in hampering the transfer of know-how to the Soviets. The systemic problems Moscow faces in assimilating and diffusing the know-how it receives are greater barriers to effective transfer of Western know-how. We believe joint ventures between the Soviets and Western firms offer the potential for facilitating some assimilation of Western manufacturing know-how needed for improving computer production

Based on past performance and our current assessments of Soviet technological capabilities, we expect the Soviets to fall further behind the West in computing capabilities throughout the 1990s. If the Soviets obtain turnkey production facilities and detailed production know-how from the West–through joint ventures for example–they would be able to narrow, at least temporarily, some specific technology gaps. Without substantial advances in computer technology, however, we believe improvements in future Soviet weapons systems will be hampered, both directly and indirectly. For example, without high-speed, high-capacity computers, Soviet ability to deploy improved anti-ballistic missile (ABM) radars for reentry vehicle discrimination and multiple target handling will be degraded. Soviet capability to design and produce the next generation of aircraft and space vehicles depends indirectly on modern CAD workstations in the laboratory and on production control and test computers on the plant floor. Computers and the integration of various computer systems for CAD, CAM, etc. are key factors in allowing the Soviets to produce complex weapons systems with short lead times and improved surge capacity. Soviet plans call for widespread introduction of computer technology in the commercial/civil sectors also. Computer-aided technologies are key elements in modernization of Soviet industry. All of these programs will require development efforts employing workstations, as well as improvements in both the quantity and quality of Soviet computer production using automated manufacturing technology from the West

If Moscow were able to legally purchase any computer equipment *not* identified above, Soviet industry could produce most of the goods likely to be required for their *indigenous* consumer and civilian industrial demand. On the other hand, if the computer equipment identified above remains embargoed, Soviet industry would have great difficulty designing, developing, and producing advanced weapons systems.

> *Key Military Applications of Computers*
>
> Computer technology affects every aspect of modern military forces, both directly as a component of weapons systems, and indirectly in the design, production, and deployment support phase. Two military programs where computers play a vital role are strategic defense and anti-submarine warfare (ASW). Strategic defense and both acoustic and non-acoustic ASW require real-time or near-real-time processing of massive amounts of data. This can be accomplished more easily with highly-advanced computing technologies.

**Advanced Manufacturing**

Manufacturing technology remains the cornerstone of virtually all weapons production, and has traditionally held a position of prominence in Soviet technological planning. While the Soviets can produce manually controlled traditional machine tools that are generally comparable to those produced in the West, they have some serious deficiencies in the production of advanced manufacturing systems, including:

➤ *Computer numerically controlled machine tools.* The Soviets realize the importance of computer numerically controlled (CNC) machine tools for development of their general industrial base. CNC machine tools are especially important to the improvement of their military production capabilities. The most important parameters for high precision machine tools—such as multi-axis precision coating machines, machining centers, mills, lathes, and grinders—and their CNC controllers, are positioning accuracy, number of simultaneously controlled axes of motion, and the number of rotating and tilting axes. Although there are many applications, both civilian and military, for machine tools with accuracies down to ±3 microns, most parts which require machine tools capable of obtaining positioning accuracies better than ±3 microns are intended for military uses. Machine tools capable of achieving this level of accuracy probably are at the limit of Soviet capability. The Soviets, however, have difficulty producing the controllers capable of operating the machines at this level, mainly due to limitations in microprocessor technology. The number of coordinated contouring axes that can be simultaneously controlled by the CNC system defines the complexity of the shape of the parts that can be produced on a specific machine tool. The production of complex shapes can allow designers to realize substantial weight reductions in their final products without sacrificing strength, which is especially important in weapon systems and aerospace hardware. CNC controllers that can simultaneously control four or more contouring axes are generally sought for these applications. Related to this is the number of axes of motion which the machine tool itself possesses. The most important axes are the rotating or tilting axes. Any machine tool capable of motion in more than one rotating *or* one tilting axis is also capable of producing key parts for military and aerospace application.

- *Precision turning machines.* The optical quality metal surfaces produced by multiple axis precision turning machines—generally having positioning accuracies of better than ±2 microns—are used in the manufacture of items such as magnetic drums and disks for memory devices, polygon mirror scanners for word processors, and reflecting mirrors for laser-related devices. While these machines have both commercial and military applications, most of the military parts require machines with a maximum slide travel of more than 100 millimeters. Some of the key subcomponents that allow these machines to achieve accuracies better than ±2 microns are laser interferometer feedback systems, precision slide motors and controls, and special algorithms for the controllers.

- *High accuracy measuring equipment.* Accurate inspection and measurement is the key to the manufacturing of consistent and reliable precision products. This is especially important in the development and production of state-of-the-art weapons and aerospace systems. The main components of a high accuracy measuring and inspection system include: workpiece sensing systems, precision machine guideways, and drive systems with mechanical repeatabilities of ±3 microns or less; and control systems which interface with both probes and the drive system.

- *Flexible manufacturing systems.* Flexible manufacturing systems (FMS) are a group of CNC machine tools controlled by a single computer system. Using information fed back from each machine, the computer determines the most efficient mode of operation for the group of machines and sends them the appropriate commands. FMSs are well suited to military production since they facilitate small lot production of high accuracy parts with a high degree of consistency. Soviet indigenous capability to produce FMSs has been extremely limited because the Soviets are deficient in producing sophisticated control system

- *Robotics.* In general, a robotic system has flexibility through the use of a computer controller that provides autonomy and reprogramability. The Soviets remain five to 10 years behind the West despite increased emphasis in research, development, and applications of robots. The USSR's problems are primarily caused by limited software development technology and limited availability of reliable components (such as servo drives and sensory systems). Western robots capable of employing feedback information from sensor systems in real-time to generate new programming (or to modify existing programming) would lead to substantial improvements in Soviet manufacturing productivity, quality, and reliability in both civilian and military applications. Robots which are specially designed to withstand explosive environments, incorporate components designed to withstand externally-induced punctures, or are designed specifically for underwater use, however, have important military utility, but little civilian application.

We believe the foregoing areas are the most important advanced manufacturing capabilities required by the Soviets to improve the performance, reliability, and efficiency of their military manufacturing base. Without access to this advanced equipment or the technologies and methods required to produce them indigenously, the quality and reliability of Soviet manufactured goods, both civilian and military, will be slow to improve

Access to any advanced manufacturing equipment and technologies will enhance Moscow's capability to produce advanced weapons systems. The systems described above, however, would result in the most substantial improvements. Most Soviet requirements for civilian industrial production could be satisfied using machines not having the advanced performance specifications listed above

*Key Military Applications of Advanced Manufacturing Technologies*

Advanced weapons systems require advanced manufacturing technologies, which directly lead to increased system performance and efficient production

Stealth aircraft. To be of practical military value, the radar cross section (RCS) of a Stealth aircraft must not only be low, it must also be repeatable for each aircraft produced and maintainable throughout the service life of the aircraft. Aircraft RCS can be significantly affected by minute changes in shape, smoothness, surface continuity, and/or materials composition. Therefore, for a Stealth aircraft, greater demands are placed on close tolerances; perfect fits; and smooth, continuous seams, joints, and connections. To manufacture these parts with consistency and accuracy, Moscow would require sophisticated CNC machine tools and high-accuracy measuring equipment

Advanced weapons systems. FMSs can provide the necessary machining quality to achieve the increasingly complex designs of modern weapons systems. These designs drive toward subsystem miniaturization and overall increased structural strength with reduced weight. Production of these systems cannot be accomplished efficiently and reliably without precise, CNC manufacturing equipment. FMSs also could help offset the steady increase in the cost of weapons manufacturing

**Telecommunications**

The national telecommunications network currently consists of a backbone of metal cable combined with extensive microwave relay and satellite communication systems and serves military, government, and civil users. The Ministry of Defense is a chief user of the network for command, control, and communication purposes. The existing network cannot support the volume of high-speed data transmissions needed for a modern, automated economy, and the Soviets are beginning to replace it with fiber-optic cable. The Soviets also plan to use fiber-optic technology in a variety of military and industrial applications such as aircraft and ship internal communications, links between machine tools and computers, and various sensors useful for antisubmarine warfare. Fiber-optic technology is particularly desirable in a military context because of increased capacity, low signal loss, reduced weight, small size, reduced vulnerability to electromagnetic pulse (EMP) effects, and enhanced security

Soviet application of fiber-optic technology is constrained by the inability of Soviet industry to produce large amounts of high-quality fiber and transmission components. The Soviets have acknowledged that production is falling short of demand for fiber and cable, both in quantity and quality. Other essential elements of a fiber-optic system are the electronic components and semiconductor lasers required to send, receive, amplify, or test the signals being transmitted through the optical fiber. The Soviet microelectronics industry has been unable to mass-produce the high quality devices needed for such component

Because of the military and intelligence implications of fiber-optic systems, and because the Soviets will not be able to provide indigenously the necessary equipment and technology for several more years, Moscow will aggressively seek to acquire:

- *Fiber production equipment.* Deficient Soviet capabilities to produce single mode 1300 nanometer fiber, and especially the more important single mode 1550 nanometer dispersion-shifted fiber, are limiting Moscow's ability to indigenously field a long-haul fiber-optic link. Equipment capable of producing such fiber, and related production know-how, are essential to Soviet communications goals.

- *Repeaters and associated electronics.* The Soviet Union has not been able to produce in large volume the electronic components required to supply the large number of repeaters required for a fiber-optic communications network. These problems are typical for all Soviet electronics, and are caused by problems with an inefficient workforce, obsolete production facilities, and poor quality control. Electronics and lasers operating at 1300 nanometers or above are key to Soviet communications goals.

- *Digital switches.* For many of the same reasons the Soviets are unable to produce adequate repeaters, they are also unable to produce in large volume the supporting multiplexing and digital switching equipment necessary for a large communications network. The Soviets are also deficient in the software required to transmit using common channel signalling. Digital switches and multiplexers—for either fiber-optic or microwave use—capable of operating at data rates at or above 140 megabits per second or incorporating common channel signalling are essential to Soviet communications goals.

- *Microwave transmission equipment.* The Soviet Union has difficulty producing equipment capable of transmitting and receiving high data rate microwave transmissions, again caused largely by lack of adequate microelectronics. Equipment capable of transmitting or receiving at data rates at or above 140 megabits per second are key to Soviet communications goals.

Shortfalls in the quality and quantity of the components needed for optical fiber manufacturing, for digital switches, and for fiber-optic and microwave transmission equipment pose a major hurdle for the Soviets. In fact, the future of Soviet indigenous, high-capacity telecommunications capabilities will depend in large measure on whether they can upgrade the capabilities of their microelectronics industry. The Soviets will continue to have difficulty obtaining telecommunications equipment and manufacturing technology from foreign sources. The East Europeans and other non-COCOM sources lack the advanced technologies sought by the Soviets. Even if the Soviets were able to purchase needed equipment and technology, the shift to an all-digital network would be slow due to the massive amount of investment and training needed to replace the existing analog systems. Nevertheless, Moscow will continue to press the US, Western Europe and Japan for aid in modernizing their own industrial capabilities as well as for equipment and supplies to be used directly in their national network.

If Moscow were able to purchase legally any telecommunications products or technologies *not* listed above, Soviet industry would have available an upgraded communications system capable of supporting most industrial restructuring. If, however, the critical needs listed above remain embargoed, then long-haul, high-capacity secure communications would not be available to the Soviet military. The military need for short-haul and for onboard systems and components probably can be satisfied from indigenous sources.

**Advanced Materials**

Although Soviet production and applications of advanced materials generally lag the West, they are able to meet most structural requirements for their military hardware by applying innovative techniques to existing materials. This, however, probably results in some degradation of individual system performance. While Soviet and Western technologies in metals and alloys are generally comparable, the Soviets lag in several key areas of composite material production and applications that could enhance the performance of some future weapon systems.

The key for the Soviets to enhance their application of advanced materials technology is advanced manufacturing equipment. Two of the main reasons the Soviets lag the West in the production and application of advanced materials are a lack of trained personnel and a shortage of automated production and quality control equipment. Moscow's most important materials technology acquisition targets are:

- *Fiber and filamentary materials technology.* Boron, carbon (graphite), aramid, alumina, silicon nitride, and new advanced organic fibers are used in military production as high performance reinforcement for weight reduction in aircraft and aerospace hardware and as ablative materials for thermal insulation. The most important elements in this area are the technologies for producing the fibers and filamentary materials; however, the technologies for production of materials for military uses are generally the same as for civilian applications.

- *Composite structures manufacturing.* This technology encompasses the design and construction of equipment and the related software to make structural parts and components from advanced composite materials. Equipment designed for fabricating composite structures with military utility includes: filament winding machines with motions coordinated and programmed in three or more axes; tape-laying machines with motions coordinated in two or more axes; and multidirectional and multidimensional interlacing machines.

- *Hot isostatic presses.* Defect elimination through hot isostatic pressing (HIP) permits production of high integrity castings at modest cost, allowing designers to increase operating stresses and temperatures of parts. This technology is used in the manufacture of high performance metal and composite aircraft components such as parts for gas turbine engines, and it is also used for parts of several nuclear devices. HIPs used for these applications generally have a controlled thermal environment within the closed cavity and are capable of obtaining working pressures above 400 megapascal

The weakest link in Soviet advanced materials programs is their manufacturing capability. We assess manufacturing methods used in the USSR to lag the West by as much as 10 years. If the Soviets were able to legally purchase the technology and equipment described above, this gap probably would narrow substantially. The most important result of this would be an improved capability to produce strong lightweight advanced weapon systems

*Key Military Applications of Advanced Materials*

Advanced materials and their associated production technologies have a direct impact in the design of military systems

Stealth aircraft. The Soviets are known to be developing Stealth missiles and aircraft. Structural composites with tailored radar absorbing or transmission characteristics are a critical element in the design of stealth aircraft. Smooth seamless composite skins made from multiple layers of materials with tightly controlled dielectric and loss characteristics, along with parasitic radar absorbing materials and paints, are used to reduce the aircraft's RCS. These advanced materials and the manufacturing technology required to employ them are essential for stealth aircraft manufacturing

Weight reduction. The use of composite materials in weapons system production can result in substantial performance improvements. They have the advantages of high strength-to-density and stiffness-to-density ratios, and the ability to design to specific loads. In missile systems and aircraft, weight reduction can result in increased range or load carrying capacity

### Soviet Requirements for Specialized Western Technology and Equipment

The five foundation technologies we have identified as essential to Soviet military systems do not, of course, represent an exhaustive compendium of Soviet needs from the West. There are a number of other technologies which, if acquired by the USSR, could be used to improve the quality or quantity of Soviet military production. There are also some commodities which, if acquired, might be used in military applications on a limited basis to fill temporary shortfalls in Soviet production. Some technologies universally cited as militarily critical--specifically, nuclear weapons design and fissionable materials production--are not included in this core list of Soviet requirements because Moscow has demonstrated over a number of years that it is capable of substantial nuclear weapons production.

Starting from a "clean sheet" approach, we judge that the five technologies we have identified will continue to represent Moscow's fundamental acquisition targets because of their widespread impact on key military capabilities (see figure 1). Other technologies, as well as commodities, could be justified as additions to this list because of their potential impact on specific Soviet weapons capabilities.

**Figure 1**
**Application of Foundation Technologies to Selected Military Areas**

| | Stealth | Anti-Submarine Warfare | Strategic Defense | Advanced Avionics | Turbine Engines | Armor/ Anti-Armor |
|---|---|---|---|---|---|---|
| Microelectronics Production Equipment | * | * | * | * | * | * |
| Computers and Peripherals | * | * | * | * | * | * |
| Advanced Manufacturing | * | | * | | * | * |
| Telecommunications | | | * | | | |
| Advanced Materials | * | | * | | * | * |