CHAPTER VI

Technology Transfer: Definition and Measurement

CONTENTS

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Discussions of the economic consequences of trade in technology for both the United States and the Communist world have been hampered by conceptual and practical difficulties in gathering and interpreting data. There is no universally accepted definition of "technology," and in many critical instances, useful data is simply unavailable. Any attempt to assess the economic importance of this trade must therefore include a discussion of the nature of technology and technology transfer and the ways in which they can be measured.

DEFINITIONS

Technology must be differentiated from science on one hand and from products on the other. Science is the pursuit of knowledge, whereas technology is the specific application of knowledge to the production of goods and services. Science flows freely across international boundaries, and even if it were possible to effectively control this flow, the prospect of doing so raises at the very least grave Constitutional questions. Some control of technology, however, is both desirable and necessary in the interests of national security because of the military or strategic capabilities it may provide.

The distinction between technology and products is more troublesome. If technology is broadly defined to mean the knowledge necessary to design, create, or implement a process; the process itself; or any services related to the process, the problem of how to treat the resulting product remains. Often this will be a "technology intensive" product, one that might be said to "embody" technology or from which the technology may be extracted through a process known as "reverse engineering "—the deduction of the techniques of manufacture from examination of the product itself. Often too technology-intensive products have military applications that cause them to pose as severe a problem to national security as the design and manufacturing know-how that went into them.

For commercial purposes, "technology" usually refers either to equipment and processes that transform raw materials into goods and services, to the training that accompany these, or to final products like computers that embody high technology, But there is little agreement, in the United States or abroad, as to exactly which products and process should be included in these categories. There are, furthermore, problems of measurement within each category. The cost of equipment or of the licenses for rights to processes, for instance, may not necessarily reflect the value to the buyer in terms of the quality, output, innovativeness, and profitability of the final product. The value of a purchase, which includes the skills of the workplace—the training required to operate machines, to achieve practical familiarity with the theoretical aspects of equipment, and to become able to adapt and extend the operation of the equipment—is difficult to quantify. Finally, there is disagreement over which products qualify as "high technology items.

To these empirical problems must be added the difficulties engendered by the fact that a number of both commercial and noncommercial vehicles exist through which technology of potential economic value is exported to the East. Commercial vehicles of technology transfer include turnkey factories (i.e., a factory built in the recipient country by a foreign firm, which is turned over to the recipient only when it is ready to "turn the key" and start production); licensing (with and without training programs): joint ventures; technical exchanges; training in high-technology areas; sale of processing equipment; provision of engineering documentation and technical data; consulting; proposals (documented and undocumented); and sale of products that embody technology. Noncommercial vehicles include visits in both directions of students, scientists, and businessmen or managers; the use of unclassified published technical data and patents; the reverse engineering of single machines or components; and clandestine activities. All of the latter modes of technology transfer cost negligible amounts of hard currency and, for the most part, have been beyond Government control. Communist states have made the most of these techniques, although they are by no means unique in this regard. These channels of technology transfer have historically been and will continue to be of great importance to market and nonmarket nations alike.

PROBLEMS OF MEASUREMENT

COMMERCIAL TRADE IN TECHNOLOGY

The most common forms of commercial technology transfer are the direct sale of products embodying high technology and various forms of industrial cooperation agreements.

High-Technology Products

The U.S. Department of Commerce recently attempted to isolate trade in high technology through the examination of exports in selected categories of the Standard International Trade Classification (SITC). This classification scheme summarizes trade information for approximately 10,000 different items by organizing it into commodity groupings. The Commerce study selected 25 categories of products which, it contends, contain all those goods that reflect best practice in critical technology sectors—machinery and transport equipment and professional, scientific, and controlling instruments (see table 14). This effort is by far the most precise and comprehensive attempt to use trade statistics to measure technology transfers.

There are problems with the Commerce list, however. Aside from quarrels over what constitutes a "high technology" good, no list based on trade data can be sufficiently detailed to precisely distinguish between levels of technology. This could be accomplished only through a case-by-case examination of individual exports in light of an accepted set of criteria defining "high technology. " The Commerce Department classifications are therefore overly inclusive; they "catch" items which do not in fact embody "high" technology, if by that is meant state-of-the-art or items unobtainable in the East. This means that calculations of high-technology trade based on these categories are inflated. Second, techniques used to value and describe exports at point of origin in the United States cannot reflect the contribution of third nations. U.S. technology embodied in products originating from American subsidiaries in Europe or Japan appears in the trade statistics of these countries and

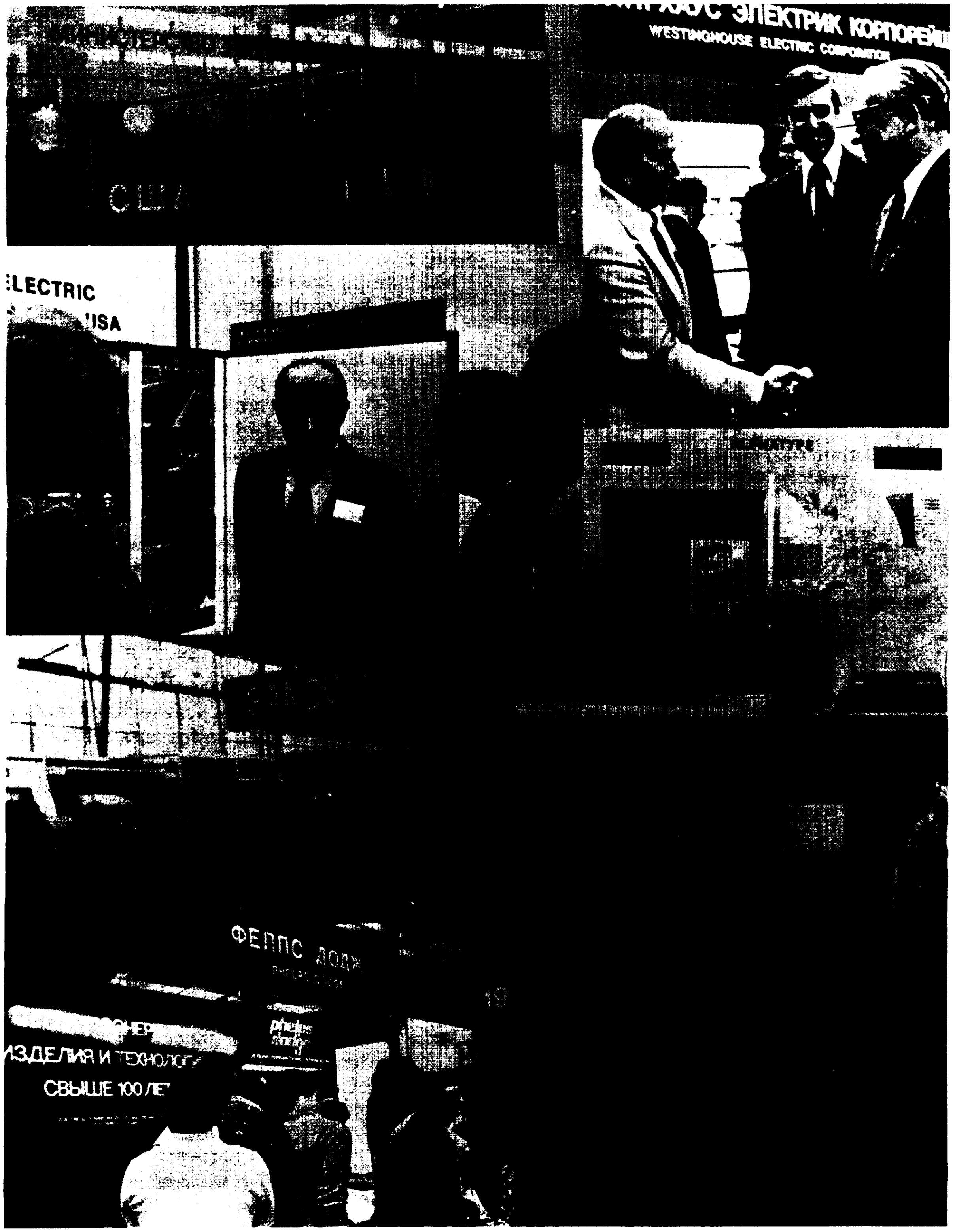

Photo credit: Bureau of East-West Trade, U S Department of Commerce

U.S.-U.S.S.R. technology transfer through the mechanism of trade fairs

Table 14.—High-Technology Items

SITC	Description
71142	Jet and gas turbines for aircraft
7117	Nuclear reactors
7142	Calculating machines (including electronic computers)
7143	Statistical machines (punch card or tape)
71492	Parts of office machinery (including computer parts)
7151	Machine tools for metal
71852	Glassworking machinery
7192	Pumps and centrifuges
71952	Machine tools for wood, plastic, etc.
71954	Parts and accessories for machine tools
71992	Cocks, valves, etc.
7249	Telecommunications equipment (except TC & radio receivers)
72911	Primary batteries and cells
7293	Tubes, transistors, photocells, etc.
72952	Electrical measuring and control instruments
7297	Electron and proton accelerators
7299	Electrical machinery, n.e.s. (including electromagnets, traffic control equipment, signaling apparatus, etc.)
7341	Aircraft, heavier than air
73492	Aircraft parts
7351	Warships
73592	Special purpose vessels (including submersible vessels)
8611	Optical elements
8613	Optical instruments
86161	Image projectors (might include holograph projectors)
8619	Measuring and control instruments, n.e.s.

SOURCE: *Quantification of Western Exports of* **High** *Technology Products to Communist Countries,* **prepared by John Young, Industry and Trade Administration, Office of East-West Policy and Planning, U.S. Department of Commerce. Project No D-41**

not in those of the United States. Finally, customs valuations are determined by the price of the sale. Price does not necessarily reflect the full market value of the commodity, however; some firms deliberately underprice an initial sale in order to break into Eastern markets.

With these reservations, and in the absence of alternative superior measures, the Commerce system has been used in chapter III to analyze U.S. and industrialized world exports of high-technology products to the Communist nations.

Industrial Cooperation Agreements

Industrial cooperation agreements have become increasingly common in East-West trade. In its most general sense, the term refers to a broad charter extending over a number of years to conduct commercial relations between a Western firm and a centrally planned economy. Industrial cooperation includes a wide variety of possible relationships, ranging from the sale of licenses and patents to coproduction agreements and turnkey plant sales. The comprehensive list incorporated into table 15 summarizes the basic mechanisms and techniques utilized in these ventures. These frequently involve relationships between trading partners which extend beyond simple sales of goods and services, to continuous and close contacts between trading partners, training, and technical assistance programs. It can be expected that these agreements lead to considerable communication of technical know-how congruent with sales of plant and capital equipment.

Activities in this area are extremely difficult to measure. Cooperation agreements are often complex and their values particularly difficult to establish because many East-West transactions involve countertrade rather than cash (see chapter III).

Countertrade is particularly attractive to Eastern nations with scarce hard-currency resources and a need to foster exports to the West. But while its importance in Communist countries is becoming increasingly apparent, little data on such agreements exist. The U.S. Department of Commerce estimates that in Poland, 40 to 50 percent of electrical products and machinery exports to the West in the 1980's will be part of countertrade agreements; and 38 percent of Soviet trade turnover between 1976 and 1980 will be generated through countertrade.[1] There are no comprehensive studies of the full range of countertrade transactions, although the Organization for Economic Cooperation and Development (OECD) has studied individual categories of contracts.[2]

[1]See U.S. Department of Commerce, *East-West Countertrade Practices: An Introductory Guide for Business,* Industry and Trade Administration, August 1978.

[2]Organization for Economic Cooperation and Development, *Countertrade Practices in East-West Economic Relations*, Paris, Mar. 23, 1978.

Table 15.—Types of Contractual Arrangements Included in Different Definitions of East-West Industrial Cooperation

1. Sale of equipment for complete production systems, or turnkey plant sales (usually including technical assistance).
2. Licensing of patents, copyrights, and production know-how.
3. Franchising of trademarks and marketing know-how.
4. Licensing or franchising with provision for market sharing and quality control.
5. Cooperative sourcing: long-term agreement for purchases and sales between partners, especially in the form of exchanges of industrial raw materials and intermediate products.
6. Subcontracting: contractual agreement for provision of production services, for a short term and on the basis of existing capabilities.
7. Sale of plant, equipment, and/or technology (l-3 above) with provision for complete or partial payment in resulting or related products.
8. Production contracting: contractual agreement for production on a continuing basis, to partner specifications, of intermediate or final goods to be incorporated into the partner's product or to be marketed by him. In contrast to subcontracting, production-contracting usually is on the basis of a partially transferred production capability, in the form of capital equipment and/or technology (on basis of a license or technical assistance contract).
9. Coproduction: mutual agreement to narrow specialization and exchange components so that each partner may produce and market the same end product in his respective market area. Usually on the basis of some shared technology.
10. Product specialization: mutual agreement to narrow the range of end products produced by each partner and then to exchange them so that each commands a full line in his respective market area. In contrast to cooperative sourcing, product specialization involves adjustment in existing product lines.
11. Comarketing: agreement to divide market areas for some product(s) and/or to assume responsibilities for marketing and servicing each other's product(s) in respective areas. Joint marketing in third markets may be included.
12. Project cooperation: joint tendering for development projects in third countries.
13. Joint research and development: joint planning, and the coordinated Implementation of R&D programs, with provision for joint commercial rights to all product or process technology developed under the agreement.
14. Any of the above in the framework of a specially formed mixed company or joint venture between the partner firms (on the basis of joint equity participation, profit and risk-sharing, joint management).

SOURCE: Offlce of Technology Assessment

Table 16 summarizes one of the most recent attempts to classify types of cooperation agreements by frequency. It shows that in 1976 coproduction based on the principle of specialization accounted for more than 38 percent of East-West agreements. This kind of transaction involves the transfer of an entire production activity to a new location, usually in Eastern Europe. After coproduction, the next most common agreements were turnkey plant sales and the sale of licenses.

Coproduction.— Under this kind of agreement, each partner specializes either in the production of certain parts of a finished product, which is then assembled by one or both partners; or in the manufacture of a limited number of articles in the production range, which are exchanged so that each partner can offer a full range of products. The technology is usually provided by one of the partners, but in some cases may be the culmination of joint R&D effort. Generally, coproduction and specialization agreements also include cooperative marketing arrangements. Usually the product bears the trademark of both partners, each of which has exclusivity for the market in its own area but shares the market in other countries. In cooperative agreements with the Soviet Union, the Western partner usually has priority for selling in the industrialized West, and the Soviet Union confines its sales to Warsaw Pact nations and possibly certain developing countries.

The attraction of such agreements for both the Western and Eastern partners is obvious. The Western firm may acquire raw materials and/or labor in the East. The Eastern country expands its repertoire of manufacture, its markets, and often its potential for earning hard currency.

Turnkey Plants.—Of all cooperation agreements, turnkey transactions are perhaps the most effective means of technology transfer. Although technology may in many cases be purchased or leased through straightforward transactions in the marketplace, turnkey projects afford the possibility of acquiring whole production systems—from feasibility studies, construction, and training through technical assistance during the initial run-in period. Further, most trans-

Table 16.—Classification of East-West Industrial Cooperation Agreements by Percent

	Total	supply of license[a]	Delivery of plant	Specialization coproduction	Subcontracting	Joint venturing and other
Survey of June 1, 1976						
Bulgaria	100.0	17.1	25.7	31.4	11.4	14.4
Czechoslovakia	100.0	27.3	—	22.7	9.1	40.9
East Germany	100.0	—	23.5	14.2	7.1	33.8
Hungary	100.0	29.5	16.3	32.6	9.6	12.0
Poland	100.0	21.7	24.2	32.3	6.4	15.4
Romania	100.0	19.4	25.5	14.2	7.1	33.8
U. S. S. R.	100.0	3.2	20.4	61.5	4.7	10.2
Total CMEA countries						
1972	100.0	**28.2**	**11.9**	**37.1**	**7.9**	**14.9**
1975	100.0	26.1	21.7	33.3	6.8	12.1
June 1,1976	100.0	17.1	20.5	38.3	7.4	16.7

CMEA= Council for Mutual Economic Assistance or Comecom.
aSupply of license in exchange (in part at least) for products or components
SOURCE: Economlc Commisslon for Europe, Unlted Nations

actions guarantee an ongoing relationship with the supplier, opening the possibility of access to developing technology. The continuity of these relationships is universally regarded as the most important single element affecting the success of a technology transfer.

Turnkey projects in their pure form, involving purchase of an entire installation from one firm or one country, are relatively rare—at least in the case of the Soviet Union. Most often, a Communist nation contracts with many Western firms for particular components of a complex, including marketing and subsidiary services. The Soviet Kama River truck plant is a good example. Here, the U.S.S.R. dealt with Western firms in several countries, assembling its own sophisticated mixture of goods and services to fit its own specifications.[3]

Licenses and Patents.—The acquisition of technology through licenses accelerates indigenous technological progress and enhances potential export capabilities in the East. According to one estimate, the purchase of a license may cause technological progress in the affected field to leap by 7 to 8 years, compared to only 3 to 5 years with the purchase of know-how and 1 to 2 years for coproduction.[4] Often the acquisition of a license creates requirements for other improvements, more imports, further licenses, and the promotion of exports. Licenses may be paid for in either currency or in products through countertrade arrangements. In Eastern Europe, the latter predominate.[5]

Licensing arrangements are varied, ranging from a straightforward authorization to exploit an individual patent to complex agreements on industrial cooperation. These may provide for the grant of licenses for using patents linked with the importation of certain capital goods; of licenses to use know-how and technical assistance in building turnkey plants or other industrial installations; and of licenses to use trademarks.

It is apparent that the diversity of modes through which technology is transferred and the complex interdependence of activities, which are directly or indirectly involved in the process, make it extremely difficult to accurately measure the value of technology that flows to the East in commercial transac-

[3]See Harlan S. Finer, Howard Gobstein, and George D. Holliday, "KamAZ: U.S. Technology Transfer to the Soviet Union," in Henry R. Nau, cd., *Technology Transfer and U.S. Foreign Policy* (New York: Praeger Publishers, 1976).

[4]See Jozef Wilczynski, "License in the West-East-West Transfer of Technology," *Journal of World Trade Law*, March-April 1977.

[5]*The U.S. Perspective on East-West Industrial Cooperation*, International Development Centre of Indiana University (Bloomington, Ind., 1975).

tions. No extensive statistical analysis of the transfer function in this respect has been made, and available data can support only crude analyses of overall volumes and trends. Any comprehensive assessment of the economic importance of these transactions would require data of a sophistication presently unavailable.

NONCOMMERCIAL TECHNOLOGY TRANSFER

Open and regular contacts between the scientific and engineering communities of the United States and the Soviet Union have received official encouragement through a number of bilateral agreements. In July 1959, a formal agreement was concluded between the U.S. National Academy of Sciences (NAS) and the Academy of Sciences in the U. S. S. R.; in the same year the International Research and Exchanges Board (IREX) began a program that sent American graduate students and young instructors to the U.S.S.R. In 1972, the U.S./U.S.S.R. Agreement on Cooperation in the Fields of Science and Technology (S&T) was completed, instituting bilateral cooperative programs in a number of scientific fields. The S&T agreement is predicated on the idea of building and maintaining a world scientific community through open channels of communication. More recently, exchanges with the People's Republic of China (PRC) have begun.

The role that such contacts have in transferring American technology with potential commercial value is the subject of considerable disagreement.

Two recent studies of the S&T agreements and the exchanges program by NAS have attempted to assess the value to both sides of the information exchanged in these programs.' Both concluded that exchanges with the Soviet Union were worthwhile, although their value to U.S. participants may be limited by American scientists' lack of familiarity with the Soviet Union's unique style of science and engineering and by the lack of Soviet candor regarding weaknesses in many areas of its research. Both programs were plagued by the rigidity of the Soviet bureaucracy (although problems with the U.S. bureaucracy seemed to rank a close second) and by erratic attendance on the Soviet side. In 1978, for example, NAS extended invitations to 44 Soviet scientists; only 4 participated.

A review of the two studies indicates that while the initial contacts provided some useful information about Soviet research (especially in the fields of medicine, weather forecasting, accelerated drug testing, nuclear fusion, magnetohydrodynamics, superconducting magnets, and earthquake prediction), the primary value of the U.S./U.S.S.R. exchanges to America has been one of educating the scientific and engineering community about the nature of the Soviet scientific system:

> Not only do U.S. scientists and engineers have the opportunity of acquiring at first hand new ideas and new perspectives from their Soviet colleagues, they also become more familiar with the relevant Soviet scientific literature and are alerted to particular Soviet scientists and engineers whose future publications likely merit special attention . . . . [The Soviets] have probably received more technical value in computer topics, in econometrics, and in management science than has the U. S., largely because the U.S. is more advanced in these areas. But the most significant value to the U.S. . . . lies in better U.S. understanding of the Soviet planning and management process, and of Soviet status and approaches in economics, management science and computer science.[7] It is nevertheless true that the United States has, on the whole, taught the Soviets more than it has learned from them. The NAS expects the future balance to shift toward greater equality.[8]

'National Academy of Sciences, *Review of the U.S./U.S.S.R. Agreement on Cooperation in the Fields of Science and Technology,* National Research Council, May 1977, and *Review of U.S./U.S.S.R. Interacademy Exchanges and Relations,* National Research Council, September 1977.

[7]1 bid., *Agreement on Cooperation,* pp. 7, 43.

'Ibid., *Interacademy Exchanges and Relations,* p. 3.

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According to NAS, the risk of inadvertently communicating important technology through scientific exchange is minimal. The Commerce Department's Office of Export Administration regularly briefs U.S. scientists on topics they should not discuss in the exchange programs, and "except in certain narrow and well-delineated fields, problems of technology do not loom large . . . The Soviets have not managed to translate into practice the wealth of American technical data already available to them through the open literature [and as a result] their technology is unlikely to benefit greatly from any further technical data we might disclose except certain specific data which are proprietary or classified."[18]

A different cost/benefit balance may exist in the student exchanges between the United States and the U.S.S.R. These can result in the transfer of technology that is difficult to quantify or even identify. Since about 1972, Soviet "students," who are usually experienced engineers, scientists, and managers of R&D establishments, have concentrated on study programs in the United States in semiconductor technology,

18 Ibid., *Interacademy Exchanges,* p. 4; *Agreement on Cooperation,* p. 43.

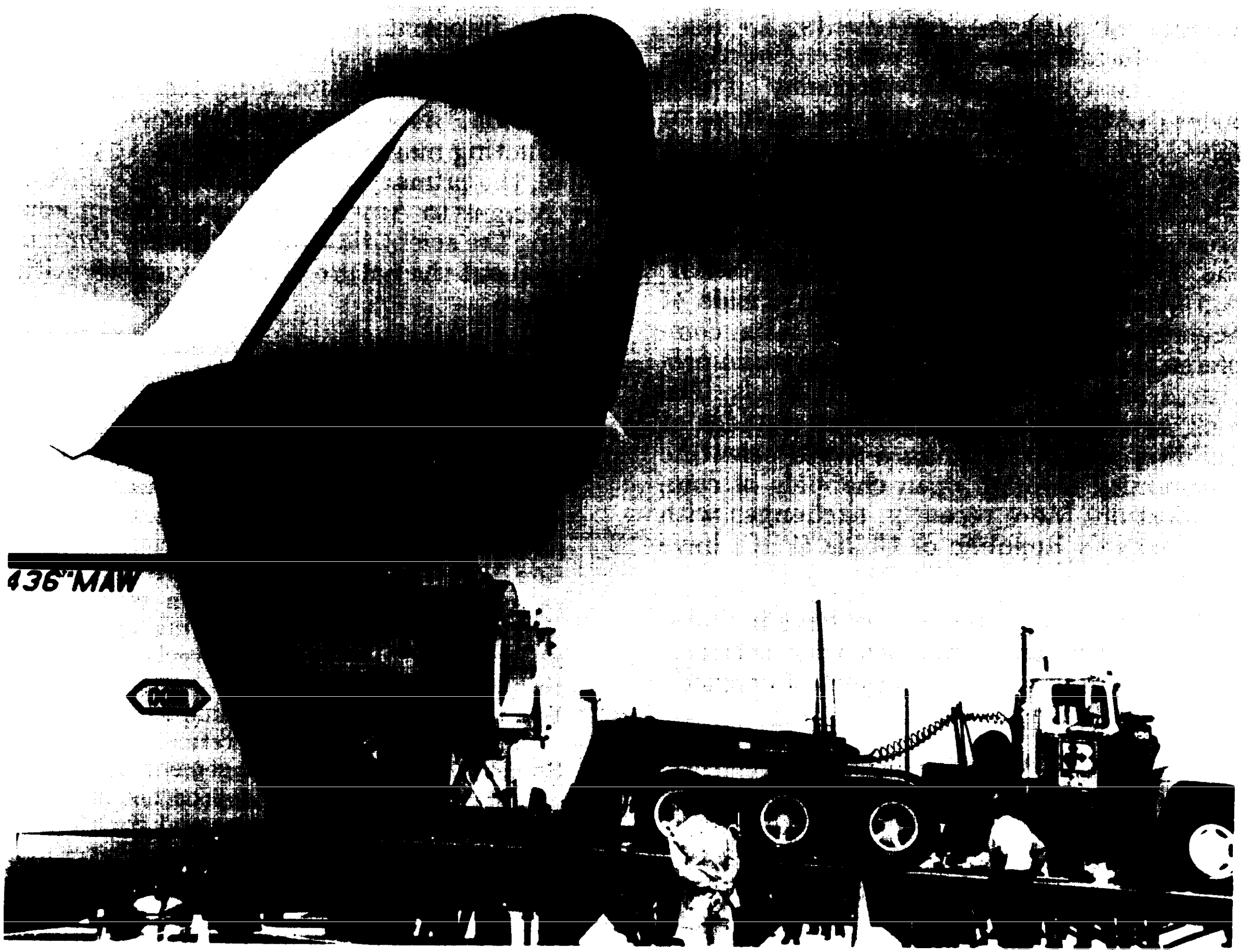

Photo credit U S Department of Energy

American magnetohydrodynamic (MHD) technology arrives in the Soviet Union as part of the U.S./U.S.S.R. Cooperation Program

computers, and other fields related to problems of applied research. Large numbers of Chinese “scholars” are similarly beginning to appear in the West. Data reflecting the number of such students and the institutions they attend tell little of the nature and amount of the technology they carry back with them. It has been alleged that this information carries potential military significance. As far as can be determined, however, no systematic attempt has ever been made to quantify its value in either military or commercial terms. Any complete assessment of such exchanges must weigh both strategic and potential commercial losses against their political and cultural value.