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25 September 1974

MEMORANDUM FOR: Chairman, Ad Hoc Working Group on Military Implications of Technology Transfer

SUBJECT : Military Implications of the Transfer of Semiconductor Technology to the USSR

1. The attached report discusses the use of semiconductor technology in the US MINUTEMAN and Soviet ICBM programs, and considers whether the Soviet ICBM program would benefit from the acquisition of US semiconductor technology. Although there are some changes in wording, substantively it does not differ from the draft submitted to you earlier.

2. This is an interim report. As you know, we plan to press our investigation further to identify the unique processing equipment and technology required to produce ICs and other semiconductors for highly specialized military use. Also, we want to examine the relationship of semiconductor technology to other military systems. We hope to prepare, at a later date, a final report summarizing the full military implications of transferring US semiconductor technology to the USSR.

[redacted]
Office of Economic Research

Attachment:
as stated

[redacted]

[redacted] (25 September 1974)

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ATTACHMENT

Military Implications of the Transfer of Semiconductor Technology to the USSR

Conclusions

- The development of a MIRV system for use on MINUTEMAN-III was aided importantly by US advances in microminiaturization of electronics subsystems -- that is, by advances in integrated circuit state-of-the-art.

- The USSR is developing MIRVs for several new variants of land-based ICBMs, but is believed to be using transistors rather than IC technology.

- The USSR probably lacks the experience and processing know-how to produce ICs to the standards of quality and reliability needed for ICBM use.

- The USSR may not be able to keep up with advances in US missile technology -- such as MARVs -- without developing IC-based guidance systems.

- The export of US IC technology to the USSR would accelerate the transition to IC-based guidance systems design.

Use of Semiconductor Technology in MINUTEMAN ICBMs

All variants of the MINUTEMAN Missile have used semiconductors in the on-board guidance system. MINUTEMAN-I used only conventional devices -- transistors and diodes -- mostly for the guidance computer. In MINUTEMAN-II and III, integrated circuits were used in a major way in the computer and to a lesser extent also in the non-computer parts of the guidance system (see Table I). The number of ICs used in the MINUTEMAN guidance system is moderately large -- about 2,600 for MINUTEMAN-II, and 2,900 for MINUTEMAN-III. These figures are deceptive because one IC performs the function of at least 16 transistors. Thus, in very rough terms, ICs in use in MINUTEMAN-II and III are equivalent to about 41,000 and 47,000 transistors, respectively which dramatically illustrates the increased complexity of the electronics systems of MINUTEMAN-II and III compared to MINUTEMAN-I (about 3,000 transistors). In general, the use of ICs has resulted in a more complex guidance system, a much more powerful computer, and improved reliability while reducing the size and weight of the entire electronic package. The development of a complex guidance system based on ICs has contributed importantly to increasing the accuracy of MINUTEMAN-II, and to introduction of MIRVs on MINUTEMAN-III.

The ICs in use in MINUTEMAN-III are relatively simple monolithic 4-gate transistor-transistor logic (TTL) types equivalent to 1964 US state-of-the-art. Functionally, they are similar to those in MINUTEMAN-II but are designed for greater reliability, enhanced resistance to degradation from radiation, and added protection against contamination.

Reliability was enhanced by strengthening all types of bonds (for example, shifting from a bimetallic to an alloy chip mount) and by reducing "purple plague" (metal migration associated with gold to aluminum bonds). Radiation resistance was greatly enhanced though the use of dielectric isolation of circuit elements and thin-film resistors, rather than junction isolation and diffused resistors. In addition, ICs used in MINUTEMAN-III employ passivation of the metalization to reduce contamination and other damage to the chip surface (see Table 2). These improvements as well as others represent extensive research and development efforts which have extended over 10 years and are continuing. Semiconductor and IC reliability problems persist, especially in the areas of wire bonds and the hermetic seals of encapsulated packages.

US advances in integrated circuit technology have contributed importantly to the development of ever more complex guidance systems, and hence, to the increased flexibility of ICBM systems. Future increases in missle flexibility -- for example the development of maneuverable warheads (MARV) -- are linked crucially to further advances in IC technology such as the perfection of non-volatile semiconductor memories.

Use of Semiconductors in Soviet ICBMs

Guidance Systems on board Soviet ICBMs historically have been less complex and less electronics-intensive than counterpart US systems; for example, they have not been fully inertial and have not used on-board computers. Because Soviet boosters are very large, and because Soviet military design philosophy stresses simplicity, especially in electronics systems, pressures to miniaturize have been small if not altogether absent. Thus, semiconductor technology has played only a minor role in Soviet ICBM development.

With the advent of MINUTEMAN-III the USSR initiated a program to develop its own MIRV capability, generating new requirements for more advanced (electronics-intensive) guidance systems. Four ICBMs now under development -- SS-16, -17, -18, and -19 -- apparently incorporate guidance systems with on-board digital computers. It is a reasonable assumption that these systems are transistorized, although it is very unlikely that they are based on IC technology. The USSR makes ICs including TTLs in adequate volume to meet the relatively small quantitative requirements of their ICBM program. However, Soviet ICs probably do not meet qualitative requirements. US experience has shown that basic TTL circuits must be modified extensively for ICBM use. The USSR has not demonstrated that they possess the experience or sophisticated processing technology needed to make all of the necessary modifications.

Soviet Interest in US and Western IC Technology

The USSR recognizes US IC technology as the best in the world and, for several years, has actively sought to purchase devices, industrial items of equipment, and whole plants. Some US IC production and test equipment has been acquired illicitly outside embargo channels. The USSR is seeking to buy, in particular, US know-how and experience. The USSR is actively procuring or attempting to procure equipment and technology in West Europe and Japan also, although neither area can match US IC technology across-the-board. The USSR seeks US and other Western technology in order to increase the quantity and upgrade the quality and reliability of IC production.

Potential Military Impact of US and Western IC Technology

Almost certainly, any US or other Western production technology acquired for use by the Soviet IC industry could be expected to serve priority military requirements as a first imperative. Soviet military authorities, which control and closely supervise the production of ICs in the USSR have first claim on output. Indeed, most of current Soviet output goes to the military, probably to research and development facilities for the design and construction of prototype electronics systems for military/space use.

In particular, acquisition of US technology probably would accelerate the development of third-generation guidance systems for use in ICBMs. There is evidence that the Soviets are dissatisfied with existing missile guidance controls and have given the development of new systems an urgent national priority. IC-based systems would enhance the reliability and probably also the accuracy of Soviet missile systems. Moreover, if the USSR is to stay abreast of US advances in ICBM design, the use of ICs in future guidance systems may be indispensable; in the judgement of US weapons experts, the development of advanced warhead designs, such as MARV, is unattainable with conventional semiconductor technology.

Table 1

Semiconductor Devices Used in MINUTEMAN On-Board Guidance Systems (in Units)

	I	II	III
Total Semiconductors			
Computer	8,139	3,918	3,911
Non-Computer	2,694	2,821	3,302
Total	10,833	6,739	7,213
Transistors and Diodes			
Computer	8,139	1,772	1,442
Non-Computer	2,694	2,387	2,853
Total	10,833	4,159	4,295
Integrated Circuits			
Computer	0	2,146	2,469
Non-Computer	0	434	449
Total	0	2,580	2,918

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Table 2

Characteristics of Semiconductors Used in MINUTEMAN Guidance Systems

	MINUTEMAN I	MINUTEMAN II	MINUTEMAN III
Diodes	Alloy junction	Diffused junction	Same as II
	Standard commercial package	Military specifications	Same as II
Transistors	MESA and PLANAR	Same as I	Same as II
	Germanium and silicon	Same as I	Same as II
	Standard commercial package	Military specifications	Same as II
			Passivation of metalization
Integrated Circuits		Monolithic TTL	Same as II
		Bimetallic bond mount	Alloy mount
		Diffused resistors	Thin-film resistors (nichrome)
		Junction isolation	Dielectric isolation
			Passivation of metalization

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