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FORM DOJ-384
2-18-77

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DEFENSE DEPARTMENT'S INITIAL MILITARILY CRITICAL TECHNOLOGIES LIST AND DEPARTMENT OF ENERGY'S LIST OF ENERGY RELATED MILITARILY CRITICAL TECHNOLOGIES

(45 Fed. Reg. 65014, 65152, Oct. 1, 1980)

(For related news item, see page A-2.)

Initial Militarily Critical Technologies List

AGENCY: Office of the Secretary of Defense.

ACTION: Notice.

SUMMARY: The Department of Defense is submitting the following list of critical technologies whose acquisition by potential adversaries would be detrimental to national security. This list was mandated by the Export Administration Act of 1979 in order to provide guidance on export control matters.

FOR FURTHER INFORMATION CONTACT: Deputy Under Secretary of Defense of Research and Engineering, International Programs and Technology, Office of Technology Trade, Room 3B1060, Washington, D.C. 20301, Telephone: 202 694-4777.

M. S. Healy,
OSD Federal Register Liaison Officer, Washington Headquarters Services, Department of Defense.
26 September 1980.

Initial Militarily Critical Technologies List

The Initial Militarily Critical Technologies List has been produced by the Department of Defense in response to Section 5(d) of the Export Administration Act of 1979, which states:

(2) The Secretary of Defense shall bear primary responsibility for developing a list of militarily critical technologies. In developing such list, primary emphasis shall be given to—

(A) arrays of design and manufacturing know-how,

(B) keystone manufacturing, inspection, and test equipment, and

(C) goods accompanied by sophisticated operation, application, and maintenance know-how

which are not possessed by countries to which exports are controlled under this section and which, if exported, would permit a significant advance in a military system of any such country.

(3) The list referred to in Paragraph (2) shall be sufficiently specific to guide the determination of any official exercising export licensing responsibilities under this Act.

(4) The initial version of this list referred to in Paragraph (2) shall be completed and published in an appropriate form in the Federal Register not later than October 1, 1980.

The Initial List has been developed by the Department of Defense, with the cooperation of other agencies of the U.S Government and U.S. industry, to identify those elements of technology the export of which to potential adversaries could increase their military capacities to the detriment of U.S. national security. The Department of Defense will periodically review and, as necessary, update and amend the Initial List as part of its continuing responsibility to protect the technology leadtime of the U.S. as compared to its adversaries in the application of advanced technologies to military capacities.

The Table of Contents for the Initial List is presented below. Detailed specifications of the list and the supportive documentation are currently undergoing Government security review. Subsequently, an appropriately modified unclassified List as refined and elaborated by the Department of Defense in cooperation with other interested government agencies, will be submitted for inclusion as part of the Commodity Control List (CCL), after consultation with our Allies, for the concurrence of the Secretary of Commerce, in accordance with the procedures stated in Section (5)(c)(2) of the Export Administration Act of 1979.

The technologies identified in the Initial List contribute to the development, production or utilization of items being controlled for national security purposes on the current CCL. The Initial List also identifies certain technologies that contribute to items on the Munitions List which have present or potential civil application.

The commodities described in the list are limited to equipment and materials so far identified as either critical to the development, production or utilization of end-items of concern or goods which would convey information concerning these activities. The list does not address end-items of intrinsic military utility; such items remain under the control of the CCL and the Munitions List. The Department of Defense may recommend that certain items on the Initial List be controlled through the Munitions List (ITAR), while certain items presently on the CCL may be recommended for decontrol.

The Initial List and associated detailed documentation of list items shall provide guidance within the Department of Defense for the review of those export license applications that particularly involve the transfer of know-how to Warsaw Pact countries. The application of the Initial List by the Department of Defense to the export of equipment will be in a manner commensurate with the CCL and the Export Administration Regulations, and will not supersede the technical definitions of the CCL until further refinement dictates suitable specification revisions.

The Initial List is itself not intended as a control list, nor is it intended as a substitute for, or an addition to, the current CCL, nor does it supplant the case-by-case review of export license applications. Further, the specificity with which the technology elements within these areas are identified in many cases needs further refinement for control decisions. Moreover, it should not be construed that technical data not listed should be freed from control.

In the Initial List, technologies are defined under four general categories:

A. *Arrays of Know-How* (including design and manufacturing know-how) are the know-how and related technical information required to achieve a significant development, production or utilization purpose. Such know-how includes services, processes, procedures, specifications, design data and criteria, and testing techniques.

B. *Keystone Equipment* (including, manufacturing, inspection or test equipment) is that equipment specifically necessary for the effective application of a significant array of technical information and know-how.

C. *Keystone Materials* are materials specifically necessary for the effective application of a significant array of technical information and know-how.

D. *Goods Accompanied by Sophisticated Know-How* are goods. 1. the use of which requires the provision (disclosure) of a significant array of technical information and know-how (including operation, application or maintenance know-how), and/or

2. for which embedded know-how is inherently derivable by reverse engineering, or is revealed by use of the goods.

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Published by THE BUREAU OF NATIONAL AFFAIRS, INC., WASHINGTON, D.C. 20037

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11.0 Microwave Technology
12.0 Vehicular Technology
13.0 Optical and Laser Technology
14.0 Sensor Technology
15.0 Undersea Systems Technology
16.0 Chemical Technology
17.0 Nuclear Specific Technology (Draft being finalized with the Department of Energy for later publication)

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14.2 Passive X-Ray Sensor Technology

14.3 Conventional Acoustic Sensor Technology

14.4 Fiber Optic Sensor System Technology

14.5 Magnetometer and Magnetic Sensor Technology

14.6 Gravity Meter Technology

14.7 Radar and Related Technology

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14.7.2 Transmitter Technology
14.7.3 Advance Radar Antenna Design Technology
14.7.4 Radar Receiver Technology
14.7.5 Signal Processing Technology
14.7.6 Display Technology
14.7.7 Radar Absorbing Material Technology

15.0 Undersea Systems Technology

15.1 Undersea Acoustic Technology

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15.1.2 Acoustic Reception Technology
15.1.3 Acoustic Transmission Technology
15.1.4 Acoustic Display Technology

15.2 Platform Acoustic Technology

15.3 Heavy Lift Salvage Technology

15.4 Deep Sea Sensor Implantation Technology

15.5 Research Facility Technology

16.0 Chemical Technology

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16.2 Hydraulic Fluid Technology

16.3 Synthetic Lubricating Oil and Grease Technology

16.4 Synthetic Elastomer Technology

16.5 Atmospheric Purification Technology

17.0 Nuclear Specific Technology

(Draft being finalized with the Department of Energy for later publication)

DEPARTMENT OF ENERGY

Defence Programs; List of Energy Related Militarily Critical Technologies

AGENCY: Department of Energy.

ACTION: Notice of publication of a list of energy related militarily critical technologies.

SUMMARY: The Export Administration Act of 1979 (PL 96–72) requires under Section 5(d) that an initial version of a list of militarily critical technologies be published in an appropriate form in the Federal Register not later than October 1, 1980. The Secretary of Defense has primary responsibility for developing this list of militarily critical technologies. In support of the Department of Defense the Department of Energy has prepared a list of energy related militarily critical technologies. This list is attached.

DATES: Comments must be received on or before December 30, 1980.

ADDRESSES: Written comments should be directed to Julio L. Torres, Director, Office of International Security Affairs, Room 5F-008, Forrestal Building, 1000 Independent Avenue, S.W., U.S. Department of Energy, Washington, D.C. 20585.

FOR FURTHER INFORMATION CONTACT:
John A. Griffin, Director, Division of Politico-Military Security Affairs, Office of International Security Affairs, Room 5F–056, Forrestal Building, 1000 Independent Avenue, S.W., U.S. Department of Energy, Washington, D.C. 20585 (202) 252–2127.
Leon Silverstrom, Assistant General Counsel for International Development and Defense Programs, Room 6F–055, Forrestal Building, 1000 Independence Avenue, S.W., U.S. Department of Energy, Washington, D.C. 20585 (202) 252–6975.

Dated at Washington, D.C. this 26th day of September, 1980.

Duane C. Sewell,
Assistant Secretary for Defense Programs.

DOE Critical Technology List

I. Introduction

This material was prepared in response to the Export Administration Act of 1979, which requires an interagency study, headed by the Department of Defense and with Department of Energy participation, of a proposed new approach to export control. The proposal suggests shifting the focus of control from end products to a set of critical technologies, in the hope that this shift of focus would provide a more effective system of controls and promote a broader range of exports without any increased risk to national security.

The attached list was developed in several iterations, with input from the National Laboratories and other selected DOE contractors. During this development a great deal of thought has been devoted to the problems of export control, and it is clear that substantially more work will have to be done to obtain a list that reflects all of the legitimate national security concerns, yet with enough specificity to be useful to export control officers.

Much of the background for the new approach to export control [1] appears to have come from the so-called "Bucy" report.[2] The new approach suggested in the Bucy report [illegible] Export Administration Act of 1979,[3] wherein the Secretary of Defense is

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federal register

Wednesday
October 1, 1980

Part VI

Department of Energy

Defense Programs; List of Energy Related Militarily Critical Technologies

DEPARTMENT OF ENERGY

Defense Programs; List of Energy Related Militarily Critical Technologies

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FOR FURTHER INFORMATION CONTACT:

John A. Griffin, Director, Division of Politico-Military Security Affairs, Office of International Security Affairs, Room 5F–066, Forrestal Building, 1000 Independent Avenue, S.W., U.S. Department of Energy, Washington, D.C. 20585 (202) 252–2127.

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Dated at Washington, D.C. this 25th day of September, 1980.

Duane C. Sewell,

Assistant Secretary for Defense Programs.

DOE Critical Technology List

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Much of the background for the new approach to export control [1] appears to have come from the so-called "Bucy" report.[2] The new approach suggested in the Bucy report is incorporated in the Export Administration Act of 1979,[3] wherein the Secretary of Defense is directed to bear primary responsibility for developing a list of militarily critical technologies and the Secretary of Commerce is directed to maintain the list as part of the commodity control list.

Following the Bucy report's recommendations, the Export Administration Act of 1979 notes that primary emphasis shall be given to:

a. arrays of design and manufacturing know-how,
b. keystone manufacturing, inspection, and test equipment, and
c. goods accompanied by sophisticated operation, application, or maintenance know-how

that are not possessed by a country to which export is to be controlled and that, if exported, would permit a significant advance in a military system of the country.

It is essential in the development of a self-consistent list of critical technologies to devise practical definitions of the key terms, including "technology," "critical technology," and "keystone equipment." There are a number of definitions of these key terms devised and used by people seriously concerned about export control and technology transfer problems.[1–4] Examining and testing these definitions helps to give us the essential ideas that must be embodied in practical ones suited for our use.

Many of the definitions of "technology" appear to be aimed at production items, and perhaps production engineering know-how, and therefore do not seem applicable to research and development technologies for advanced or undeveloped concepts. Thus, according to such definitions, the US does not have a "fusion technology," or a "beam weapon technology" because we do not have the know-how to design let alone manufacture machinery or products to do those [illegible]. Yet, there are portions of the activities in these as well as other R&D programs that should be considered for export control.

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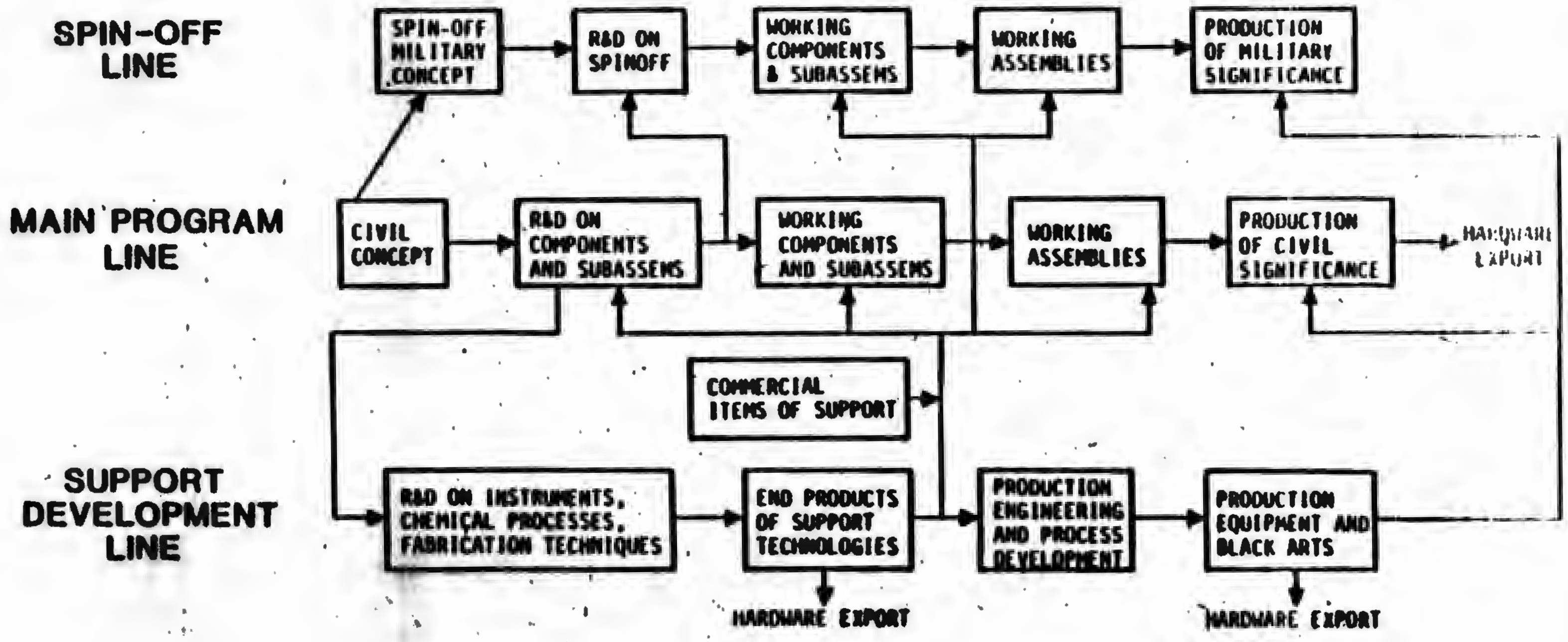

FIGURE 1

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A difficulty encountered in definitions of "critical technology" is that there is usually no time scale considered. Yet in deciding whether or not to license an export, a staff member must make some evaluation of the time it might take for the exported technology or hardware to appear as an adversary capability. In some cases the time may be so long that the capability would no longer be a threat. In other cases this may not be true. An ideal definition of critical technology would embody the condition that even after the time it takes for the adversary nation to absorb and apply the technology, it would still be considered critical. It seems especially important to keep in mind that some "high technology" R&D programs may require many years to yield a product, but the pay-off may be so great that it is wise to protect the relevant technology today. In the early stages of such a program, that is, before classification limits exchange, either side may benefit. Controlling exports or exchanges early in a development time scale therefore carries a risk.

In existing definitions of "keystone equipment" consideration of equipment required for advanced research and development activities is often overlooked. In such advanced studies, where problems of design are not yet solved, it is impossible to know what kind of equipment, materials, or components will be uniquely required for the manufacture of some final product. On the other hand, keystone equipment for the research and development phases can be identified.

In consideration of the difficulties of using definitions from other sources for selection of candidate hardware and ideas for export control, we propose the following ones for this study:

1. Technology. A specific technology is the body of knowledge acquired in the application of scientific principles to the solution of a specific technical problem.

Broader definitions of technology may be found, but are not appropriate in this report. Note that parts of the body of knowledge may be taken from other bodies of knowledge acquired previously, and parts may be acquired accidentally. The technical problem may be the construction of one magnetically confined fusion machine or the production of a large number of integrated circuits. It may also be an analysis of a new approach using existing hardware in a different way to solve the ABM problem. The quality of the end product depends upon the quality of the technology.

2. Critical Technology. A critical technology is a technology that would provide an adversary with information detrimental to the security of the U.S.

Note that a decision regarding whether or not a technology is detrimental to the security of the United Stated may involve evaluating time scales as discussed earlier. Some technologies are not likely to result in hardware production for a number of years, but others in the hands of an adversary may produce an effect within a very short time. Note also that whether or not some form of the technology is available in other countries does not alter the characterization of the technology as "critical." It does affect the decision whether or not to export the technology. Furthermore, determining whether a US technology enjoys a competitive advantage is too subjective an evaluation to be a significant concern in this analysis. A US technology may appear attractive to an adversary because it reveals something about vulnerabilities in a related product used for military purposes, or because it indicates something of value about a related but reserved technology.

In these cases the competitive advantage of the product may be at best of only secondary importance. Finally, the fact that a technology has civil as well as military applications (dual-use) creates special concerns about the licensing of exports of the technology, but it has no bearing on whether the technology is "critical." It is only important to determine whether there can or will be a significant adverse impact on US security, whether it be military, economic, or political.

Figure 1 illustrates a way to summarize the kinds of equipment that are part of the reduction of a concept to practice. In the figure, a so-called "main program line" indicates an assumed project to produce some object for civil use. We have further assumed that there is a closely related concept for a military device that requires some of the same technology. The progress of the defense related concept toward production of a device proceeds along the "spin-off line." Supporting both programs or projects is the "support development line," which provides any kind of special hardware, equipment, process, etc. used in the programs for construction or instrumentation. This special hardware also requires some development work of its own. If there is to be production at the ends of the lines, there is a production engineering or process development activity that culminates in the means for production. Possibilities for exporting the technology that characterizes this effort occur at any or all stages along the main program line and the support development line, but the spin-off line begins to be affected by classification at some point. Hardware can be exported also from the main and support effort as indicated in the figure. The earlier in the sequence of events the export takes place, the less important it would appear to be to require control. There are, of course, exceptions.

Keystone equipment can be identified at the R&D stages and at the production stage as special equipment, hardware, or processes developed to solve major problems in the respective stages. Considering that keystone items comprise more than just "equipment," we propose finally to change the description of these items to "keystone hardware," with the understanding that chemical or other processes are to be included.

3. Keystone Hardware. Keystone hardware is unique hardware components that are necessary for the effective development or application of a technology.

Keystone R&D hardware would include, for exxample, superconducting magnet wire and exploding bridge wire detonators. Examples of keystone production hardware would include unique manufacturing equipment, inspection and testing equipment, raw materials with special characteristics, and the chemical engineering equipment and materials needed for critical processes. The types of production problems solved include major improvements in rates of production and/or the quality of the product.

The list we have developed so far is a list of important technologies related to nuclear weapons research, development, and production that may be critical technologies. Certainly this list does not at this time constitute the set of technologies recommended for export control. Development of final lists, integrated with DoD efforts, will require substantial further effort.

II. DOE Critical Technologies List

A. Discussion

Table I is a list of technologies compiled from submissions by the DOE National Laboratories and appropriate DOE contractors. Accompanying the list of technologies are lists of hardware items associated with the technologies. Military and civil applications of the technologies and foreign availability information complete the table.

All of the technologies overlap or impact in some way upon the technology of nuclear weaponry. They are all therefore "critical" to some degree. We believe that this list is best viewed as a starting point for more strict application of criteria important to controlling the export of US technology and hardware. In its present form, the table may be valuable in calling attention to areas of concern, but additional more detailed descriptive material is needed to help with decisions on real export cases.

Most entries in the "keystone hardware" column are themselves the end products of more primary technologies. There is, for example, a homopolar generator technology (II.B.), which has associated with it such keystone hardware as flywheels, bearings, brushes, magnetic coils, and others. It is not now clear to us how much to subdivide these technologies.

There are so many modern technologies that involve computer assistance in one way or another that we simply omitted reference to it except where it was particularly brought to our attention by someone in the business. A number of categories not so flagged in the table should have a "calculation technology" subheading and should have "computers" as keystone hardware.

In a collection of R&D technologies such as presented in Table I, the associated keystone hardware can seldom be classified as "associated end products," as the export act seems to call for. What we can list, however, are hardware items that are associated in some way with the technology. These items are either components of the main and spin-off development lines, or instrumentation of other support hardware that are crucial to the execution of these development lines. There is only an end product when the development program is successfully concluded. In a sense, then, the hardware items become more like indicators of the kind of work being carried out in the main program. Controlling the export of such equipment may force certain inconveniences or hardships on foreign scientists, even though the equipment itself is not directly of defense significance. It has been argued, however, that in the end, if foreign scientists are forced by export controls to invent their own support equipment, they will be more knowledgeable about the subjects than if they had been allowed to buy them.

In Table I, applications are sometimes listed for the entire main category, and if there are further applications for some of the keystone hardware items, they are listed additionally.

Finally, there are many "Black Arts" or tricks of the trade, which we cannot list as keystone hardware, but which may be just as essential to the proper operation of some process or piece of equipment as the hardware itself. These arts or tricks usually work in the direction to protect our technologies, so it's probably well to leave them unpursued.

B. Critical Technologies Table

1. Index to Table

I. Nuclear fuel cycle technology.
a. Uranium enrichment.
1. Gaseous diffusion.
a. UF_6 transport and purification.
b. Diffuser technology.
c. Calculation technology.
d. Reserved.
e. Reserved.
f. Feed/withdrawal technologies.
2. Gas centrifuge.
a. Rotor design technology.
b. Bearing design technology.
c. Suspension design technology.
d. Bellows mfg. technology.
e. Drive system mfg. technology.
f. Suspension system mfg. technology.
g. Reserved.
h. Reserved.
i. Reserved.
j. Reserved.
k. Reserved.
l. Flow system technology.
m. Auxiliary technologies.
n. Computer software technology.
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a. Computer modeling technology.
b. Laser technology.
c. UF_6 handling technology.
d. Molten U handling technology.
e. Ion extraction technology.
f. Atomic vapor source technology.
g. UF_6 spectroscopy.
h. Atomic U spectroscopy.
i. Switching technology.
j. Reserved.
4. Plasma process.
a. Superconducting magnet technology.
b. U plasma technology.
5. Calutron technology.
a. Magnet technology.
b. Source technology.
6. Aerodynamic processes.
a. UF_6 flow technology.
b. Skimmer technology.
7. Chemical exchange.
a. Contactor technology.
b. Uranium compound handling technologies.
c. Recycle technology.
d. Materials handling technologies.
B. Reprocessing technology.
C. Heavy water production technology.
1. GS process technology.
2. Vacuum distillation technology.
3. D_2O analytical technology.
D. Fuel fabrication.
1. Pellet fabrication technology.
2. Cladding technology.
3. Coated particle technology.
E. UF_6 production.
1. Uranium oxide hydrofluorination technology.
2. UF_6 fluorination technology
3. UF_6 purification technology.
4. HF mfg. technology.
5. Fluorine mfg. technology.
F. Fission reactors.
1. Pressure vessel technology.
2. Cooling cycle technology.
3. Control technology.
4. Maintenance technology.
5. Safety technology.
G. Electro-nuclear breeders.
II. Fusion technology.
A. Very high power laser technology.
B. Charged particle accelerator technology.
C. Fusion pellet technology.
1. Pellet fabrication technology.
2. Computer software technology.
D. Magnetic confinement technology.
1. Superconducting magnet technology.
2. Switching technology.
3. Plasma technology.
4. Materials technology.
E. Imploding liner technology.
1. Computer software technology.
2. Switching technology.
3. Implosion system technology.
F. Impact fusion technology.
1. Impactor technology.
2. Computer software technology.
G. Diagnostics technology.
III. Reactor production of nuclear materials.
A. Tritium production technology.
B. Tritium handling technology.
C. Pu-239 production technology.
D. Pu-239 fabrication technology.
E. Pu-238 mfg. technology.
F. Reserved.
G. Reserved.
IV. Nuclear weapons technology.
A. Computer technology.
1. System mfg. technology.
2. Component mfg. technology.
3. Interactive graphics technology.
4. Operating systems technology.
B. R&D technology.
1. Computer calculations.
a. Language technologies.
b. Code technologies.
2. Development testing technology.
3. Live nuclear test technology.
4. Componet fabrication technology.
C. Production technology.
D. Special component technologies.
E. Special materials technologies.
1. Fabrication technologies.
2. Purification technology.
3. Pyrotechnics fabrication technology.
4. Thermite composite fabrication technology.
5. Plasma polymerization technology.
6. Explosive recrystallization technology.
7. Large diameter high pressure storage vessel technology.
8. Paper honeycomb fabrication technology.
9. Silicone adhesive technology.
10. Nickel carbonyl [$Ni(CO)_4$] coating technology.
11. Thin film hydriding technology.
12. Electrical feedthrough technology.
V. MHD.
A. Superconducting magnet technology.
B. Materials technology.
C. Liquid metal handling technology.
D. Plasma studies.
VI. Advanced seismic detection.
A. Seismometer technology.
B. Signal processing technology.

C. Da and command transmission and reception technology.

VII. Satellite technology.

A. Detector technology.

B. Data transmission and reception technology.

VIII. Electronics.

A. Semiconductor mfg. technology.

IX. Safety, security, and survivability technology.

A. Reserved.

B. Encryption technology.

C. Electronically assisted physical security.

D. Weapon survivability.

E. Reserved.

DOE Critical Technologies

Critical technologies	Keystone hardware	Military applications	Civil applications	Foreign availability
I. Nuclear fuel cycle technology				
A. Uranium enrichment		Nuclear weapons, nuclear propulsion, space power reactors, portable power reactors.	Power reactors, research reactors	
1. Gaseous diffusion				UK, France, USSR, FRG, Netherlands, PRC, Sweden, Switzerland.
a. UF_6 transport and purification	UF_6-rated materials of construction.			
	Compressors			France, UK, FRG, USSR, PRC.
	Rotating shaft seals (inert gas buffered).		Seals for reactive gas systems, e.g. fluorine.	
	Valves for UF_6	Valves for reactive gas systems	Valves for reactive gas systems	Widely available.
	Heat exchangers for UF_6	Heat exchangers for e.g., fluorine	Heat exchangers for e.g., fluorine	France, UK, USSR, PRC.
	Cleaning solvents			
b. Diffuser technology	Barrier material, Diffuser housings, Nickel powder.	Battery plates, filters, alloys	Battery plates, filters, alloys	UK, Canada.
	Porous nickel metal			
	Barrier manufacturing equipment.			
c. Computer software technology	Computers	Many uses	Many uses	UK, France.
d. Reserved				
e. Reserved				
f. Feed/withdrawal technologies				
2. Gas centrifuge				USSR, UK, Netherlands, FRG, Japan, France, Pakistan, Australia, Italy, Switzerland, Sweden, Brazil.
a. Rotor design technology	Rotors			
b. Bearing design technology	Bearings			
c. Suspension design technology	Suspension systems			
d. Bellows mfg. technology	Bellows forming dies and mandrels.			UK, France, Japan, others.
	Hydraulic forming equipment (isostatic presses).	Many uses	Many uses	UK, FRG, USSR, France, Japan, others.
	Maraging steel			
e. Drive system mfg. technology	Synchronous motors (600–2000 Hz) High frequency steel.		Textile mills, high speed grinders	Widely available.
f. Suspension system mfg. technology	Magnets (metallic or ceramic dampers).		Loud speaker magnets	Widely available.
g. Reserved				
h. Reserved				
i. Reserved				
j. Reserved				
k. Reserved				
l. Flow system technologies	Valves, bellows sealed, nickel, monel or nickel plated.			UK Switzerland, FRG, France.
	Pressure transducers for UF_6		Chemical processing industry	FRG.
	Al alloy piping		Chemical processing industry	
	Process computers			France, FRG.
m. Auxiliary technologies	Vacuum systems, Vacuum pumps.			FRG, others.
	Purge systems			USSR, UK, Netherlands, FRG.
	Balancing equipment			FRG.
	Leak detectors			UK, FRG.
	Mass spectrometers			UK, FRG.
	Inverters, converters, frequency changers and generators, 3-phase 600–2000 Hz.		Textile mills, high speed grinding equipment.	UK, FRG, Japan.
	Electrical power supplies			UK, FRG.
n. Computer software technology	Computers			
3. Laser isotope separation		Separation of fissile isotopes	Purifying materials, processing reactor wastes.	Canada, France, FRG, Japan, S. Africa, UK, USSR.
a. Computer modeling technology	Computers			
b. Laser technology		Laser guided weapons	Chemical analysis, photochemistry	USSR, France, Israel, FRG, Japan, others.
	Tunable diode lasers and amplifiers.			
	Tunable IR & UV lasers and amplifiers.			
	Tetrodes (>1 MW)			
	High efficiency high rep. rate copper lasers and amplifiers.			
	Electro-optical components			USSR, France, Israel, FRG, Japan, others.
	Excimer lasers and amplifiers			
	Tunable dye lasers and amplifiers.			

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DOE Critical Technologies—Continued

Critical technologies	Keystone hardware	Military applications	Civil applications	Foreign availability
	Very high power dye lasers			
	Equipment for growing diode crystals.			
c. UF_6 handling technology				USSR, France, FRG, UK, Netherlands, Israel, Japan, S. Africa, Brazil.
	Supersonic nozzles UF_6 compatible materials of construction.			
d. Molten U handling technology				
	Crucibles			
e. Ion extraction technology				
f. Atomic vapor source technology				
	Electron beam heated vapor sources (high power strip sources).			
g. UF_6 spectroscopy	Tunable diode lasers UV spectroscopy.			
h. Atomic U spectroscopy				
	Tunable dye lasers			
i. Switching technology (~ 1000 pps, high current.				
	Power supplies			
	Thyratrons			
	Spark gaps			
	Low inductance capacitors			
j. reserved				
4. Plasma process a. Supercond. magnet technology.		MHD generators, magnetic flux savings (ASW), supercond. propulsion systems.	MHD generators, Maglev transport, magnetic ore prospecting.	Japan, UK, FRG, France, USSR, Italy.
	Supercond. magnets			
	Magnet wire			
	Coils Cryogen handling equipment.			
	Winding and joining equipment.			
b. U plasma technology Materials of construction.	Magnets for large volume, uniform fields.			
	Plasma forming equipment			
5. Calutron technology				
a. Magnet technology Magnets for large uniform fields Regulated high current supplies.				
b. Source technology	Regulated high voltage supplies.			
6. Aerodynamic processes				FRG, S. Africa, Brazil, Sweden.
a. UF_6 flow technology				France, UK, USSR, FRG, PRC.
	Compressors for UF_6, UF_6-rated materials of construction.			
	Rotating shaft seals			
	Heat exchangers			
b. Skimmer technology				FRG, S. Africa, Brazil.
7. Chemical exchange				
a. Contactor technolgy	Contactors with low stage residence times (~ 20 s).	Plutonium and fission product separation.	Chemical process industries, waste treatment, many others.	France, Sweden, FRG, UK, Japan, many others.
	Centrifugal liquid-liquid contactors.			
	Pulse column liquid-liquid contactors.			
	Other multistage liquid-liquid contactors.			
b. Uranium compound handling technologies				UK, FRG, France, USSR, S. Africa, PRC, Japan, others.
	Materials of construction			
	Fluoroplastics or fluoroplastic-lined pipe, valves, pumps, other equipment.		Many chemical processes	Many industrialized.
	Specialized uranium extractants	Fuel reprocessing-Pu recovery	Power reactor cycle, plastics, chloralkali, Chemical analysis.	Many industrialized countries.
	Electrolysis diaphragm materials.			
	Ion exchange resins (particular).			
c. Recycle technology	Cells for reduction by electrolysis (especially mercury-cathode diaphragm cells).		Chloralkali industry	Many industrialized countries.
	Specialized multiple effect evaporators.		Chemical process industry	Many industrialized countries.
	Reverse osmosis systems which withstand high acid concentrations.			
d. Materials handling technologies	See designated (*) items under "Reprocessing Technology".			8
. Reprocessing tehnology		Nuclear material production	Power reactor fuel cycle	Belgium, France, FRG, India, Italy, Japan, Taiwan, UK, USSR.
	Fuel shears			

DOE Critical Technologies—Continued

Critical technologies	Keystone hardware	Military applications	Civil applications	Foreign availability
	*Criticality safe tanks			
	*Centrifugal contactors			
	*Mixer settlers			
	*Pulse columns			
	Dissolution equipment			
	Tributyl phosphate			
	*HEPA filters			
	*Ion exchange mat'ls which will withstand intense radiation.			
	*Off-gas treatment systems			
	Manipulators for hot cells			
	Shielding windows for hot cells.			
	*Process control instrumentation.			
	Radiation monitoring instrumentation modified for fuel reprocessing.			
	*Computers			
C. Heavy water production			Power reactors	Canada, France, USSR (?), Norway (?), India, Argentina.
1. GS process technology				
	Packed tower contactors		Chemical industry	Canada, India.
	Gas blowers for H_2S Water pumps.		Water purification	
	Heat exchangers			
	Condensers			
	Piping			
	Valves			
	Tanks			
	Storage vessels			
	Gas compressors			
	Process instrumentation			
	Water treatment equipment			
	Steam generating equipment			
2. Vacuum distillation technology			Chemical industry	
	Towers			
	Steam ejectors			
	Vacuum pumps			
	Water pumps		Water purification	
	Calandrias			
	Condensers			
	In process storage tanks			
3. D_2O analytical technology				
	Single beam infrared spectrophotometry.			
D. Fuel fabrication		Nuclear propulsion, nuclear materials production.	Power reactor fuel	France, USSR, Canada, FRG.
1. Pellet fabrication technology	Pellet presses			
	Sintering furnaces			
	Grinding and grading equipment.			
	Inspection equipment			
	Assay equipment			
2. Cladding technology				France, USSR, Canada, FRG.
	Welding equipment			
	Inspection equipment			
	Leak detection equipment			
	Tubing mfg. equipment			
	Hf-free zirconium			
	Zirconium casting vacuum furnaces.			
3. Coated particle technology	Spherical particle fabrication equipment Particle coating equipment.			
	Presses			
	Binder materials			
	Furnaces			
E. UF_6 Production		Feed for enrichment plant	Feed for enrichment plant	USSR, France, FRG, Belgium, UK, Japan, PRC, S. Africa, Italy, Canada.
1. Uranium oxide hydrofluorination technology (to produce UF_4).	Screw reactors		Chemical industry	
	Stirred fluid-bed reactors		Chemical industry	
	Fluid-bed reactors		Chemical industry	
	Inconel pipe		Chemical industry	UK, Canada.
2. UF_4 fluorination technology (to produce UF_6).	Flame towers		Chemical industry	Canada.
	Fluid beds		Chemical industry	
	Monel pipe		Chemical industry	UK, Canada.
3. UF_6 purification technology	Distillation columns			France.
	Absorption traps			
	Nickel-plated steel pipe			
	Bellows-sealed valves			UK, France, Switzerland.
4. HF manufacturing technology	Calcium fluoride		Chemical industry	
	Sulfuric acid			
		Chemical industry		

DOE Critical Technologies—Continued

Critical technologies	Keystone hardware	Military applications	Civil applications	Foreign availability
5. Fluorine mfg. technology	Fluorine cells	Rocket fuel	Fluorocarbon manufacture	UK, France.
	High density carbon anodes			
	Hydrofluoric acid (HF)			
	Potassium fluoride			
	Chlorine trifluoride			
F. Fission reactors		Propulsion, electric power	Electric power, process heat	Canada, USSR, FRG, France, Japan, UK, Belgium.
1. Pressure vessel technology	Very large rolling mill			
	Welding equipment			
	Inspection equipment (x-ray, sonic, etc.)			
	Very large forging machinery			
2. Cooling cycle technology	Pumps			
	Heat exchangers			
	Pressure, temperature, flowrate instrumentation.			
	Clean-up systems			
	Valves			
	Heavy water			
3. Control technology	Computers			
	Control rod drives			
	Monitoring instrumentation			
	Sensible poisons			
4. Maintenance technology	Fuel element handling equipment.			
	Inspection equipment			
5. Safety technology	Computers			
	Monitoring equipment			
	ECCS equipment			
	Inspection equipment and procedures.			
G. Electro-nuclear breeders			Electric power production	
	High current accelerators			
	Targets			
	Ion sources			
	Switching equipment			
II. Fusion technology		Nuclear mat'ls production, neutral beams, RF systems, effects simulation.	Electric power production	Canada, France, FRG, Italy, Japan, Poland, UK, USSR.
A. Very high power laser technology		Laser weapons, effects simulation	Welding	
	Very high power lasers			
	Very high power amplifiers			
	Mechanical and electro-optical hardware.			
	High voltage systems (pulse power).			
	High current high rep. rate switches with low jitter.			
	Pointing systems			
	Single point diamond cutting lathes.			
	Diamond tools			
	Optical coating equipment	Optical equipment	Telescopes	
	Optical polishing equipment for large optical elements.		Telescopes	
	Other ultrahigh precision equipment.			
	Gas handling equipment			
	NaCL windows			
	Glass components			
	Flash lamps			
	Electron beam pumping equipment.			
	Other pumping equipment			
B. Charged particle accelerator technology		Particle beam weapons, weapons physics simulation, neutron sources.	Physics research, medical research, x-ray machines.	USSR, France, PRC, others.
	Linear induction accelerators			
	[illegible]			
	Heavy ion accelerator modules			
	High energy density capacitors			
	Superconducting magnets			
	Homopolar generators			
	High rep. rate high current switches with low jitter.			
	Large thermionic cathodes			
	Pulsed alternators			
	Pointing systems			
	Computers			
	Ion sources			
	Electron sources			
	Vacuum system equipment			
C. Fusion pellet technology				
1. Pellet fabrication technology	Pellets			
	Pellet manufacturing equipment			

DOE Critical Technologies—Continued

Critical technologies	Keystone hardware	Military applications	Civil applications	Foreign availability
	Pellet loading equipment (D_2 gas handling, etc.).			
	Tritium handling equipment			
	Pellet sorting and inspection equipment.			
	Pellet manipulation equipment			
2. Computer software technology	Computers			
D. Magnetic confinement technology		MHD propulsion, MHD lasers, explosive MHD.	MAGLEV transportation Explosive MHD.	Japan, FRG, UK, USSR, European community.
1. Superconducting magnet technology	See I.A.4.a.			
2. Switching technology	Power supplies			
	Energy storage components			
	Thyratrons			
	Spark gaps			
	Low inductance capacitors			
3. Plasma technology	Power supplies			
	Capacitors			
	Switches			
	Gyrotrons	Microwave transmission, jamming		
	Neutral beam injectors			
	Plasma clean-up equipment			
	Flushing systems			
4. Materials technology	First wall materials			
	Other materials of construction.			
E. Imploding liner technology			Electric power production	Poland, USSR.
1. Computer software technology	Computers			
2. Switching technology	See I.D.2			
3. Implosion system technology	Magnets	Nuclear and non-nuclear weapons		
	Liners			
	High explosives			
	Lasers			
	Plasma guns			
	Other plasma preparation equipment.			
F. Impact fusion technology				USSR, France.
1. Impactor technology	Multi-stage gas guns			
	Specially developed projectiles.			
	Electromagnetic guns			
	High energy density capacitors.			
	Switching equipment			
	Rotating flywheel energy storage systems.			
	Propellants			
	Targets			
2. Computer software technology	Computers			
G. Diagnostics technology	Streak cameras	Nuclear weapon development		
	Neutron detectors			
	Gamma detectors			
	X-ray detectors			
	Fast analog circuitry			
	Fast oscilloscopes (pico-second range).			
	Computers			
	X-ray transmission equipment			
	Neutron radiography equipment			
	Microwave acoustic microscopy equipment.			
	Spectroscopy equipment			
	Magnetic field measuring equipment.			
	Thompson scattering equipment.			
	Interferometry equipment			
	Pin probes			
	Flash X-ray equipment			
	Diagnostic lasers			
II. Reactor production of nuclear materials				
A. Tritium production technology		Nuclear weapons	Fusion reactors, self luminous components, batteries, sensors, D-T neutron sources.	France, PRC, UK, USSR.
	Reactors			
	Lithium alloys			
	Distillation equipment			
	Lithium-target fabrication equipment.			
	Tritium recovery equipment			
	Calorimeters			
B. Tritium handling technology		Nuclear weapons		France, PRC, UK, USSR, Hungary, Netherlands, Poland.
	Pumps			
	Valves			
	Piping			
	Mass spectrometers			
	Absorption beds			
	Glasses with special diffusion properties.			
	Monitoring instruments			
C. Pu-239 production technology		Nuclear weapons	Breeder reactors for electric power production.	UK, France, USSR, PRC, India.
	Reactors			
	Target fabrication equipment			

DOE Critical Technologies—Continued

Critical technologies	Keystone hardware	Military applications	Civil applications	Foreign availability
	Fuel shears			
	Solvent extraction equipment			
	Dissolution equipment			
	Ion exchange materials and equipment.			
	Off-gas treatment systems			
	Glove boxes			
	Analytical chemistry equipment			
D. Pu-239 fabrication technology		Nuclear weapons		UK, France, USSR, PRC, India, Argentina, Japan, Taiwan.
	Equipment for reduction to metal.			
	Casting furnaces			
	Graphite molds			
	Glove boxes			
	Metallurgical equipment			
	Metal forming machinery			
	Equipment for production of oxides, nitrides, carbides of Pu.		Mixed oxide (nitride, carbide) fuels for breeders.	
	Pellet presses		MOX	
	Analytical equipment			
	Sintering furnaces		MOX	
	X-ray machines			
	Metallographic equipment			
	Other measuring equipment			
E. Pu-238 manufacturing technology		Heat source for thermoelectric power generation.	Heat source for thermoelectric power generation.	USSR.
	Reactors			
	Np-237			
	Fuel shears, dissolution, separation, precipitation and reduction equipment.			
F. Reserved				
G. Reserved				
IV. Nuclear weapons technology		Nuclear weapons	Plowshare, Orion, Rover	UK, France, USSR, India, PRC.
A. Computer technology		Many	Many	France, FRG, Japan, UK, USSR.
1. System manufacturing technology	High performance, high capacity computers.			
	Cooling systems			
2. Component manufacturing technology	High performance, high capacity peripheral memories (discs, tapes).		Many	
	Magnetic bubble memories (See VIII.A.).			
3. Interactive graphics technology	Interactive terminals		Many	
4. Operating systems technology	Interactive terminals, Other I/O.		Many	
B. R&D technology 1. Computer calculations	Computers, Terminals, Printers.	Many	Many	Many countries.
a. Language technologies				
b. Code technologies				
2. Development testing technology	Pin technique equipment	Explosives research	Ballistics	
	High speed framing cameras	Explosives research	Fusion technology	
	High speed streak cameras	Explosives research	Fusion technology	
	Flash x-ray machines	Explosives research		France, Sweden.
	Image intensifiers		Radiology	
	Microdensitometers			FRG.
	High explosive firing equipment.	Explosives research	Prospecting	Many countries.
	Firing site	Explosives production and research.		
	Particle accelerators	Particle beam weapons, effects	Flash x-ray	France, USSR, PRC, others.
	Computers for data reduction			
3. Live nuclear test technology				UK, France, USSR, India, PRC.
	High speed oscilloscopes	Laser weapons, radar, others	Fusion technology	
	High speed digitizers		Fusion technology	
	High speed counters			
	High quality large diam. coax cables.		TV transmission	
	Fiber optics cables and components.		Telephone cables	
	Photomultiplier tubes	Neutron, gamma detectors, others	Fusion technology, others	
	Time domain reflectometers			
	High speed calibration and data recording equipment.		Fusion technology	
	Radiochemistry equipment			
	Large-hole drilling equipment			
	Computerized network analyzers.	Missile component testing		Sweden.
	Microdensitometers	Photo analysis	Photo analysis	France, UK.
	Image enhancement equipment	Info. processing, remote sensors	Info. processing, LANDSAT, earth resources sensing.	France, UK.
4. Component fabrication technology				UK, France, USSR, PRC, India.
	UF_4 to metal conversion equipment.			
	PuO_2 to metal conversion equipment.			
	Uranium casting equipment	Uranium penetrators		
	Uranium machining equipment	Uranium penetrators		
	Depleted or natural U components.	Uranium penetrators		

DOE Critical Technologies—Continued

Critical technologies	[illegible] hardware	Military applications	Civil applications	Foreign availability
	Enriched U components			
	Plutonium casting equipment			
	Plutonium machining equipment			
	High explosives casting equipment	High explosive shells, bombs, etc.		
	High explosives pressing equipment	High explosive shells, bombs, etc.		
	High explosives machining equipment			
	Electrochemical machining equipment	Aircraft	Aircraft	
	Explosive forming facilities			
	Shear forming equipment			
	Isostatic and hydrostatic presses	Conventional munitions	Aircraft engine parts	
	Electron beam welding equipment	Many, aircraft parts	Pipelines, medical uses, aircraft	
	Laser welding equipment			
	Many	Many		
	Filament winding machines	aircraft parts, rocket motors, reentry vehicles		
	High-precision 2-5 axis NC machine tools	Ordnance, aircraft parts	Tool & die mfg., ceramics, aircraft parts	Japan, FRG, France, Italy, UK, Switzerland, Belgium
	Dimensional-inspection machines (contact, non-contact, laser)	Many	Many	
	Frequency synthesizers	Radar, communications and ECM equipment		
	Spectrum analyzers	Radar, communications and ECM equipment		
	Laser holography equipment			
	X-ray holography equipment			
	X-radiography equipment			
	Laser interferometry equipment			
	Laser feed back systems	Mirrors	Laser fusion technology	France.
	Rotary and linear feedback systems	Aircraft, naval, ordnance parts	Tool & die uses, engine parts	Switzerland, FRG, Japan.
	High-precision spindles (air bearings and vibration isolation)	Mirrors	Laser fusion, other optics	Japan.
	High precision linear induction motors	Mirrors	Laser fusion, other optics	Netherlands.
	High precision lead screws	Mirrors	Laser fusion, other optics	UK.
	Single point diamond inserts	Mirrors	Laser fusion, other optics	FRG, Netherlands (?), S. Africa (?), Israel (?), USSR (?).
	Numerically controlled systems hardware	Many	Auto, machinery, aircraft production	
	Advanced NC systems		Nuclear reactors	
	Leak detection equipment for 10^{-14} cc/s	Neutron generator tubes	Hermetic seals, IC mfg., electron tubes	Japan.
	Electron microprobes			France.
C. Production technology	See IV.B.4			
D. Special component technologies	High voltage power sources (battery driven)	Smart bomb & missile fuzing	Accelerators	
	Exploding bridgewire detonators		Blasting	
	Cold cathode switches (Krytrons, sprytrons)			
	Neutron sources		Oil well logging, uranium logging, neutron standards, neutron radiography, neutron medicine	The Netherlands, USSR.
	High-energy density capacitors			
E. Special materials technologies 1. Fabrication technologies	Filamentary materials	Reentry vehicles, aerospace components	Space vehicles, aerospace components	Japan, France.
	Composite materials	Aerospace components, structures	Aerospace components, structures, gas & liquid storage	France.
	Boron-10	Naval reactor propulsion systems	Reactor controls	USSR.
	Beryllium	Guidance systems, optical systems, structures	Electronics components, x-ray windows, space systems	France, USSR, UK
	Beryllium-stainless steel alloys			
2. Purification technology	Ultrahigh purity rare earths (Sc & Y)			
3. Pyrotechnics fabrication technology	Metal hydride synthesis facilities	Ordnance weapons, missiles	Fireworks, valve actuators, gas	Many countries.
		Deterrent containers	Propulsion	
4. Thermite composite fabrication technology	Special compaction dies	Ordnance weapons, deterrent containers	Welding, deterrent containers	Many countries.
5. Plasma polymerization technology (thin films)	Plasma coaters and cleaners	Ordnance weapons	Protective coatings for corrosion prevention	
6. Explosive recrystallization technology		Ordnance weapons	Commercial explosives, explosive devices	
7. Large diameter, high pressure storage vessel technology				
8. Paper honeycomb fabrication technology	Hobe machine	Aircraft, missiles	Aircraft	

DOE Critical Technologies—Continued

Critical technologies	Keystone hardware	Military applications	Civil applications	Foreign availability
9. Silicone adhesive technology	Vinyl-addition potting equipment.	Reversion-free, in-place potting	Many fabrication processes	
	Blown-silicone cushion equipment.	Low compression-set pre-load pads	Long life and out-gas-free assemblies.	
10. Nickel carbonyl [Ni(CO)₄] coating technology.			Corrosion prevention, sealing, Mechanical envelope.	
11. Thin film hydriding	Thin film targets	Neutron sources	Oil exploration, uranium exploration, neutron medicine, neutron standards, neutron radiography.	UK, Netherlands, USSR.
12. Electrical feedthrough technology	Cermet feedthroughs	Neutron sources	Neutron radiography	Netherlands, USSR
V. MHD		Electric power generation, propulsion.	Electric power generation, magnetic fusion, topping cycle for steam power plants, explosive driven MHD for earthquake prediction, deep electrical sounding.	France, FRG, Japan, UK, USSR, Poland.
A. Superconducting magnet technology	See I.A.4.a			
B. Materials technology	Electrodes			
	Channels			
	Seed materials			
	Combustion chamber			
	Large valves			
	Slag condensation systems			
	Seed recovery systems			
	Heat exchangers			
C. Liquid metal handling technology			LMFBR's	
	Pumps			
	Heat exchangers			
	Metal-gas separators			
	Nozzles			
D. Plasma studies			Magnetic confinement fusion	
VI. Advanced seismic detection		Nuclear test detection	Earthquake detection	USSR, Sweden.
A. Seismometer technology	High sensitivity seismometers			
	Wide band seismometers			
	Remotely operated equipment			
B. Signal processing technology	Computers			
C. Data and command transmission and reception technology.	Satellites			
	Digitizing circuitry			
	Authentication logic			
VII. Satellite technology		Nuclear test monitoring, weapons intelligence, weapons delivery, global positioning satellites, ABM detection, intell. monitoring.	Astrophysics observations, geophysics observations, meteorological observations, LANDSAT monitoring.	PRC, USSR, Japan.
A. Detector technology	Radiation detectors			
	Photo diodes			
	Photomultiplier tubes			
	Radiation hardened electronics.			
	Receivers			
	Transmitters			
B. Data transmission and reception technology.				
VIII. Electronics				
A. Semiconductor mfg. technology		Proximity fuzes, missiles, electronic warfare, radars, communication and navigation, weapon control, battlefield information, others.	Computers, control systems, consumer goods.	Japan, France, Hong Kong, Singapore, others.
	Microprocessors	Many	Many	Japan.
	Charge coupled devices			
	Continuous process tantalum sputtering equipment.			
	Photolithographic masks			
	Automated inspection equipment.			
	LSI circuits			
	VLSI circuits	Telemetry, conventional weapons, comm. and control.	Electronic equipment	FRG, Italy, Japan, Netherlands, USSR.
	Silicon photodiodes			
	Gallium arsenide and gallium phosphide devices.	High temperature uses		
	E-beam equipment for chip etching.			
	UV equipment			
	X-ray equipment			
	Equipment for bonding with silver.	Electronic equipment	Electronic equipment	FRG, Japan, UK.
	Wafer steppers	Electronic equipment	Electronic equipment	
	Ion implantation equipment (for wafers larger than 2" diam.).	Electronic Equipment	Electronic Equipment	
	Hyperpure Ge	Gamma ray detection	Gamma ray detection	
	Radiation hardened discrete, LSI, and VLSI circuits.			
	Parylene coating equipment			
	Clean rooms			
	Wire bonding machines			
	Diffusion furnaces			
	Computers for circuit analysis			
IX. Safety, security, and survivability technology.		Security of nuclear weapons, site, security, safeguards.	Industrial security, fiscal security	
A. Reserved				

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DOE Critical Technologies—Continued

Critical technologies	Keystone hardware	Military applications	Civil applications	Foreign availability
B. Encryption technology	Microprocessors			
C. Electronically assisted physical security		Weapon storage site protection	Power plant protection	
	Sensors			
	Microprocessors			
	Signal processing equipment			
D. Weapon survivability	Sensors			
	Microprocessors			
X. Reserved				

C. Technology Descriptions

I. Nuclear Fule Cycle Technology

A. Uranium Enrichment. The only naturally occurring fissile material suitable for use in nuclear weapons is uranium-235 (^{235}U). It makes up approximately 0.71% of natural uranium. Some nuclear reactors contain only natural uranium fuel. Others require enriched fuel, that is, the fuel must be made of uranium that has been processed so that the ^{235}U concentration is higher than 0.71%. For use as fissile material in nuclear weapons, uranium must be highly enriched. The gaseous diffusion method of enrichment, which depends on the fact that the rate of diffusion of a gas is inversely proportional to the square root of its molecular weight, has been the method used. It requires a large plant with many (several thousand) diffusion stages, and has high power requirements. Some of the newer technologies developed or under development offer possible cost advantages for large scale production, and may be more adaptable to smaller scale use.

B. Reprocessing Technology. Reprocessing is required for optimal use of reactor fuel, whether the goal is plutonium production for weapons, or production of power. Plutonium-239 (^{239}Pu) is a suitable fissile material for weapons and for reactor fuel. When ^{238}U is exposed to thermal neutrons, as in a reactor, ^{239}U is formed by neutron capture, and decays by beta emission to ^{239}Np, then to ^{239}Pu. For recovery of the ^{239}Pu thus formed in reactor fuel elements, reprocessing is required. Various other isotopes of Pu also are formed, some of which are undesirable for use in weapons. Suitable fuel management and refueling timing can minimize their formation and obviate the need for Pu isotope separation, as well are reduce the safety hazards during reprocessing.

Uranium-233, which is also fissile and does not occur in nature, can be produced by neutron capture by thorium-232. Its recovery also requires reprocessing.

C. Heavy Water Production. Heavy water (also known as deuterium oxide, D_2O) occurs in nature. Using ocean water as a reference, the atomic abundance of deuterium in natural hydrogen is 0.0140%.

Three methods for separating D_2O from light water have been known for many years. Electrolysis of water and distillation both preferentially concentrate D_2O in the residue. Similarly, in the reaction $H_2O + D_2O$ — $D_2 + H_2O$, the reverse reaction predominates, and at equilibrium the ratio of ^2H to ^1H in the liquid phase (i.e. D_2O to H_2O) is about three times as great as in the phase (that is D_2 to H_2).

Heavy water is of interest to the weapons community because it is a source of deuterium for the D-T reaction of thermonuclear weapons, and because of the fuel usage and conversion characteristics of heavy water moderated nuclear reactors. Heavy water moderated reactors, such as Canada's CANDU reactors, can be fueled with natural uranium, and have fairly high conversion ratios of ^{238}U to ^{239}Pu because of deuterium's very low neutron capture cross section. They therefore allow the possibility of production of weapons grade fissile material without need for access to uranium enrichment. This is also possible using graphite as a moderator, but it is not possible using ordinary water.

D. Fuel Fabrication. Fabrication of reactor fuel elements is a necessary link in the chain of processes leading from raw uranium ore to the use of reactors for power or the production of weapons grade plutonium. Dependence on an outside supplier of fuel elements may make it difficult or impossible for the possessor of a reactor to manage refueling timing to optimize ^{239}Pu production. Technology used in the fabrication of some types of fuel elements may also be applicable to the facrication of weapons components. For example, glove box lines, alpha-counters, machine tools, and other equipment would be the same, or similar.

E. UF6 Production. Uranium hexafluoride (UF_6) is the most volatile uranium compound known. At room temperature it is a dense white solid with a vapor pressure of 120 mm, but it can be readily sublimed or distilled. The gaseous diffusion enrichment process, as well as other enrichment processes such as the gas centrifuge use UF_6. See section I. A. for discussion of enrichment.

F. Fission Reactors. Many aspects of fission reactor technology are useful in providing a technology base for nuclear weapons development. For example, computer codes for calculating the progress of reactor excursions may be applicable to analysis of weapon neutronics. Reactors also provide the ability, to varying degrees, to breed or form ^{239}Pu from ^{238}U, and tritium from ^6Li, for use in weapons. Experience with nuclear instrumentation and familiarity in dealing with radiation problems are also helpful in a weapon program. Criticality experiments for weapon design studies resemble some of the aspects of reactor operation. Operation of research reactors would be especially good experience.

G. Electro-nuclear Breeders. Electro-nuclear breeder technology, to breed ^{239}Pu or ^{233}U with the aid of fission sustained with the assistance of neutrons generated from a target bombarded by high energy particles, is of interest for two reasons. The fissile material that is bred can be used in weapons, and the charged particle source and accelerator technologies developed can be applied in other critical areas.

II. Fusion Technology

A. Laser Technology. Laser technology has many possible critical applications, ranging from isotope enrichment to laser guided weapons to laser weapons. Supporting technologies for high voltage systems also have multiple applications. Energy storage and switching equipment is common to most directed energy systems.

B. Charged Particle Accelerator Technology. This technology is necessary in some approaches to inertial confinement fusion, in directed energy weapons studies, fusion reactor materials development, and to some extent in magnetic confinement fusion and basic physics research. The relevance of accelerator technology to national defense makes it a critical technology in a military sense, but it is also critical politically and possibly economically as well. Research and development in this area is well advanced in the USSR, and there has tended to be rather unrestricted exchange between the USSR and the US concerning new component design concepts. At the same time, no one is sure that exchanged information has included the most highly developed refinements.

C. Fusion Pellet Technology. Aspects of fusion pellet technology may have direct applicability to fusion weapons.

D. Magnetic Confinement Technology. Plasma studies of MHD stability in magnetic confinement could support understanding of weapons hydrodymamics. Also deuterium and tritium reaction rate studies as well as the technology of handling these materials would be transferable to weapon programs.

E. Imploding Liner Technology. Implosion technology has been fundamental to nuclear weapon development since the days of Fat Man. Modern calculation technology, detonation systems, and experimental diagnostics all still have application to weapons.

F. Impact Fusion. To achieve impact fusion, a massive (by controlled inertial fusion standards) target of a few milligrams of deuterium and/or tritium is accelerated to velocities of the order of 10^6 m/s. A difficult part of the technology is achieving sufficiently high speeds to bring the material together forcefully enough to cause fusion.

G. Diagnostics Technology. Diagnostics instruments for controlled fusion, with requirements to function under conditions of high temperature, in a radiation environment, or with very short time response characteristics, are also important in nuclear weapons testing. Some fusion diagnostic equipment is useful also in nuclear weapon R&D programs for diagnosing the hydrodynamic performance of device mockups.

III. Reactor Production of Nuclear Materials

A. Tritium Production Technology. Tritium (T) is produced in nature by the action of cosmic radiation on nitrogen in the upper atmosphere. It is also produced as an unwanted contaminant in the water coolant of reactors, and may be produced through neutron bombardment of lithium-6 by the reaction

$$n + {}^{6}Li \rightarrow {}^{4}He + T + 4.8 MeV$$

It is of interest because of its use as a fuel in thermonuclear weapons. Deuterium (D) is naturally occurring, and fusion may be made to occur between two deuterium nuclei. However, the peak reaction rate coefficient of the D–D reaction is considerably less than that of the D–T reaction.

B. Tritium Handling Technology. Tritium is a beta emitter. Being an isotope of hydrogen, it can enter into all the chemical reactions of hydrogen, including those in the body. Gaseous tritium is not significantly absorbed into the body, but water containing tritium is. It can be taken up through the lungs or mouth or absorbed through intact skin and is dispersed through all the body fluids, though exchange with the hydrogen in other body tissues is slow. In addition to its radioactive health hazard aspects, tritium has all the handling difficulties of ordinary hydrogen, with higher safety and cost penalties for failure. Experience in the handling of the material would be valuable in a weapon program.

C. Plutonium-239 Production Technology. Plutonium does not occur in nature except in very minute quantities. Several isotopes are known. Plutonium-239 is produced by neutron absorbtion by ^{238}U and subsequent beta decay. It is a fissile material that can be separated chemically from uranium, an easier process than the isotope enrichment techniques needed to produce highly enriched uranium. Plutonium can also be used as a reactor fuel. A weapon made of plutonium can be smaller in size than a comparable weapon made of uranium. Contamination of ^{239}Pu with other Pu isotopes can make it less desirable for weapons and increase the hazards of handling it.

D. Plutonium-239 Fabrication Technology. Nuclear weapons components must be fabricated with good precision. Plutonium is a difficult and hazardous material to handle. It is toxic and an alpha emitting carcinogen. Plutonium is very complex, metallurgically. Working with ^{239}Pu, as with any fissile material, requires that caution be exercised to avoid forming a critical mass when it is unintended.

E. Plutonium-238 Manufacturing Technology. Pu-238 is an alpha emitter with a half-life of 86 years. It is useful in radioisotope-powered thermoelectric generators and has been used for such applications as powering seismic and other experimental instruments on the lunar surface for Apollo missions. Unique handling difficulties arise from the fact that alpha decay keeps it at a relatively high temperature. Some of the processing and handling equipment for Pu-238 is the same as for weapon grade plutonium.

F. Reserved.

G. Reserved.

IV. Nuclear Weapons Technology

A. Computer Technology. A very important element in a modern nuclear weapon R&D program is the correlation of experimental data with self-consistent theoretical models. Computers provide a convenient and effective way to carry out such correlations and to predict improvements within the limitations of the models. Modern computer manufacturing technology comprises not only the manufacturing technology of highly integrated solid state circuits, but also includes the general architecture of the system, that is, its logic flow, peripherals, operating system, and other overall characteristics. A very crucial element is the cooling system design.

Computers are very powerful tools in many areas of research as well as in development and production of all kinds of hardware of military interest. Large scale production and use of computers at least has the potential of affecting the economics of production management in many areas. Many U.S. companies have a competitive edge because of the wide use computer controlled processing.

Computer manufacturing technology is thus considered critical because of the wide applicability of such machines throughout all levels of industry. Loss of the U.S. advantage in computer availability could be detrimental to the security of this country.

B. R&D Technology. Nuclear weapon research and development methodology has developed in the U.S. over thirty-five years to a rather sophisticated state. The methodology is optimized to "fine-tune" weapon designs, guarantee reliability, explore the limits of design, and reveal new phenomena that can affect the next generation of weapons. The U.S. nuclear weapon R&D technology as a whole may not mesh well with the aims and intentions of another country, but knowledge of it and access to the associated hardware would be a boom to a new program if only to save the time and effort consumed in reinventing ways to acquire data, and assessing which are the important pieces of data to be gathered in the program. It is worth a great deal to know which particular ways to fabricate workable components, which ways to carry out critical tests, and which methods to gather data actually work best. We would estimate that years could be saved in an R&D effort if these technologies and hardware were widely available.

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C. Production Technology. Nuclear weapon "production" is not production in the usual American sense of the word. There are very few processes in the final manufacturing that were developed especially for the production phase. Materials certification, fabrication techniques and inspection are for the most part the same as those used in the R&D portions of the programs. Final assembly and packaging are additional large scale activities that characterize nuclear weapon production, but aside from these, production technologies are substantially the same as R and D component fabrication processes. There are advantages to doing things this way. Processes are developed at no cost to the production program, and development testing is done on components that are going to look very much like the final production items. For production of a limited number of complex objects, the system is optimum.

Some portions of the fabrication technologies are critical because of the unusual requirements of working with nuclear materials. Making good parts of these materials is a non-trival undertaking. In other cases there are "Black Arts" develped which give good yields, or special materials must be used to avoid compromising the performance of the end device. These technologies are critical because knowledge of them can result in a better product, a higher yield of acceptable parts, a less expensive process, or a more timely appearance of a new design.

D. Special Component Technologies. This category of technologies is critical because in general the technologies have been expensive and time consuming to acquire, and result in end products that are crucial to the reliable and proper functioning of a nuclear weapon. The problems solved by these technologies may be solved in other ways, but generally speaking the US technology is advantageous in the context of the US ground rules. Knowledge of these technologies could give relief from design constraints in developing programs, and allow advantages in time, system architecture, and support facility complexity.

E. Special Materials Technologies. These are some of the technologies that are supportive of the component fabrication technologies described earlier. Each requires development time, each provides some kind of advantage to the system design engineer, and each results in an overall advantage to the end product. The final improvement in a complex and highly optimized assembly may be large even though an improved component manufacturing technique may seem relatively minor. These supporting technologies are critical in the sense that they make available to an adversary some of the design edge that a seasoned manufacturing array possesses.

V. MHD

When a thermally ionized gas or a conducting liquid is forced at high temperature, pressure and velocity through a duct situated in a transverse magnetic field, an induced voltage appears in the third mutually perpendicular direction, and this voltage may be tapped by electrodes within the duct. The heat required may come from combustion, nuclear power or solar energy. Magnetohydrodynamics (MHD) has the long range potential, when combined with a bottoming cycle, for producing electricity from coal combustion with an efficiency of about 50%. MHD can provide a portable system for conversion of chemical to electrical energy with high efficiency.

A. Superconducting Magnet Technology. Superconducting magnets are used in magnethohydrodynamics applications to achieve intense fields with low loss. Superconducting magnet technology is also of use in several other areas of interest.

B. Materials Technology. MHD makes heavy demands on materials technology. High performance electrodes must operate in a high temperature, high velocity, corrosive environment. The channel must also survive the hostile environment. Niobium and titanium are useful for the superconducting magnets.

C. Liquid Metal Handling Technology. Liquid metal handling technology developed for use in MHD applications in which liquid metal is the conducting fluid is also applicable to liquid metal breeder reactors, which can produce fissile material for use in weapons or in reactors.

D. Plasma Studies. Study of plasma stability problems under various conditions of implosion and explosion can lead to an improved understanding of weapons hydrodynamics.

VI. Advanced Seismic Detection

This technology is critical in the sense that improvements in current seismometer technology, signal processing technology, transmission and reception technology, and integrated circuit technology may allow better detection thresholds and more accurate yield calibrations for underground shots. These improvements could be important in proliferation detection and n-th country device yield estimation. Currently the big problem to overcome in threshold detection appears to be background noise, and so one might expect that the best chances for improvement would be in signal processing to read through the noise, or in methods to suppress noise.

VII. Satellite Technology

A. Detector Technology. Satellites provide one of our principal means for detecting clandestine nuclear bursts in the atmosphere or in space near the earth in monitoring for treaty compliance, and monitoring for proliferation indications. Substantial amounts of intelligence can be gained about the level of sophistication of weapon design, as well as about the existence and location of a test. This information can be especially important in the case of a first test by an n-th nation. Knowledge of specific performance parameters of satellite detection systems could enable others to design countermeasures to deceive the detection systems and thereby reduce the information available to us in this vital area.

B. Data Transmission and Reception Technology. Data gathered by satellite-borne detector systems is of value only to the extent that it can be transmitted to and received by earth stations. The quantity of data that must be transmitted may be greatly reduced, and the effectiveness of encryption applied to it enhanced by inclusion on the satellite of memory and computing power, which are made possible by microminiturization of components to permit the achievement of sophisticated processing with minimal weight and power requirements.

VIII. Electronics

Every facet of the US defense capability depends upon electronics and most depend specifically on semiconductor electronics. Furthermore electronics has very significantly impacted upon the US production economy. Computerized processing, controlling, and recording have enabled US industry to sustain significant increases in productivity. Electronics technologies are critical because they are in widespread use, are very powerful in solving certain kinds of problems, and control the functions of sensitive defense systems.

A. Semiconductor manufacturing technology. The basic ideas of semiconductor functioning are of course widely known. Integrated circuits are collections of semiconductor elements and passive circuit elements in a single package. The critical factor in these packages is the manufacturing processes and machinery. Developments in automated fabrication and inspection procedures have made possible more reliable, more versatile, smaller packages that can perform a greater array of functions. These fabrication processes are known to some extent world wide, but only a few countries are working at the edge of the technology. Preserving the US lead in these manufacturing technologies is critical to the maintenance of superior equipment for defense and an economic advantage in goods for export.

IX. Safety, Security, and Survivability Technology

A. Reserved.

B. Encryption Technology. Encryption technology is used for the concealment of information. It supports compaction of information to reduce transmission requirements. Encryption is also used to control identification or validation keys in many applications in which it is necessary for equipment to verify the identity of an individual or the validity of an order, before granting access to the individual or obeying the order. Knowledge of advanced encryption technology may both improve an adversary's capabilities in his own use of encryption, to our detriment, and enable him to penetrate our systems, gaining information, gaining access, or causing the execution of false commands.

C. Electronically Assisted Physical Security. Technology relating to the physical protection of weapons facilities should be considered for protection from export. The understanding of this technology provides insight into ways of defeating the protective measures. Extensive R&D relative to protection in the commercial nuclear reactor area has been conducted for several years within the DOE laboratories. Much of this information has been made available through the International Safeguards program to foreign countries and in that regard may be too late to protect. Nevertheless, newer and more sophisticated computer-based techniques for analyzing data from sensors around a protected area are being developed. These techniques reduce false alarm incidence and provide intruder tracking in a way that vastly improves the protective capability of an intrusion detection system. Both the system operational capability and the related devices represent strongly sensitive areas in the overall physical protection of facilities.

D. Weapon Survivability. In defining semiconductor technology that should be protected from export, one extremely innovative area that should be considered is the application of microprocessors and microcomputers. These powerful control devices are showing up in many of our most modern weapon systems. The manner in which these devices carry out their control and monitoring function could be extremely sensitive since that information could well point to vulnerable aspects of the system. In the area of future application of microcomputers in weapon systems, the area of adaptive control should be considered. The microcomputer contains the mathematical capability to implement complex adaptive algorithms to reprogram a weapon based on measured data on the well-being of critical components or environmental factors. Thus, the microcomputer could well provide the ability for the weapon to sustain substantial damage and still be reprogrammed to accomplish its mission. The Russians have for years developed advanced adaptive control theory and techniques. The microprocessor provides both them and us the opportunity to develop self-healing weapon systems. Applications of microcomputers to such problems should be treated as sensitive technology.

X. Reserved.

References

1. Chapman, Ray E., "Proposed New Approach to Export Control," DOE/OISA memorandum to distribution dated Aug. 14, 1978, unclass.
2. J. Fred Bucy, et al., "An Analysis of Export Control of U.S. Technology—A DoD Perspective," a report of the Defense Science Board Task Force on Export of U.S. Technology, written at the request of USDDR&E, February 1976, unclass.
3. Export Administration Act of 1979, 50 USC APP 2401, Sec. 5D.
4. Herbert Kleiman, "Final Summary Report on Identification of Strategically Significant Technologies," work done at Battelle Columbus sponsored by Dept. of Defense Research and Engineering International Programs Office, January 1978.
5. "A Methodology for the Identification of Militarily Critical Technologies," Meyer Consultants, March 31, 1980, as modified by the (IDA) Critical Technologies Project.

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