(12) LEVEL III

IDA REPORT R-258

THE CRITICAL TECHNOLOGIES PROJECT

Executive Summary

Ronald A. Finkler, *Project Director*

January 1981

Prepared for

Office of the Under Secretary of Defense for Research and Engineering

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION

IDA Log No. HQ 81-23259

The work reported in this document was conducted under contract MDA 903 79 C 0018 for the Department of Defense. The publication of this IDA Report does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that agency.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: REPORT R-258	2. GOVT ACCESSION NO.: AD-A107 488
3. RECIPIENT'S CATALOG NUMBER:	
4. TITLE (and Subtitle): The Critical Technologies Project Executive Summary	5. TYPE OF REPORT & PERIOD COVERED: December 1979 - October 1980
	6. PERFORMING ORG. REPORT NUMBER: Report R-258
7. AUTHOR(s): Ronald A. Finkler, Project Director	8. CONTRACT OR GRANT NUMBER(s): MDA 903 79 C 0018
9. PERFORMING ORGANIZATION NAME AND ADDRESS: INSTITUTE FOR DEFENSE ANALYSES, 400 Army-Navy Drive, Arlington, Virginia 22202	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Task T-0-072
11. CONTROLLING OFFICE NAME AND ADDRESS: Deputy Under Secretary for International Programs and Technology, OUSDR&E, The Pentagon, Washington, DC 20301	12. REPORT DATE: January 1981
	13. NUMBER OF PAGES: 93
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office): DoD-IDA Management Office, 400 Army-Navy Drive, Arlington, Virginia 22202	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE: None

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

None

18. SUPPLEMENTARY NOTES

N/A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

The Export Administration Act of 1979, Militarily Critical Technologies List, Critical Technology Approach, Chemicals and Materials, Transportation, Telecommunications, Avionics, Navigation and Naval Equipment, Semiconductors and Electronic Components, Electronic Instrumentation, Computers, Strategic Trade Control, Export Control

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report provides an overview of the Critical Technologies Project whose objective is to develop for DoD recommended entries for the Militarily Critical Technologies List (MCTL) in selected technology areas for their consideration as a first step in meeting the Congressional mandate to introduce an MCTL into the export control procedures. This report is an executive summary of work performed by the IDA/DoD/Industry Technical Working Groups (TWGs).

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Contract MDA 903 79 C 0018
Task T-0-072

i/ii

PREFACE

This document constitutes the Executive Summary of the IDA Critical Technologies Project for FY 1980. The project is reported in its entirety as follows:

Report R-258 The Critical Technologies Project (U), Executive Summary

Summarizes the work of IDA, the Technical Working Groups (TWGs), and those who otherwise participated in the IDA project. Sketches the overall Department of Defense (DoD) project of which the IDA project was a major part.

Technical Working Group Reports

These constitute the complete report of the joint IDA/DoD/Industry TWGs. Sections I and II of each were written and reviewed by the TWG Chairmen. The substantive analyses and recommendations were produced and reviewed by each TWG as a whole.

Study S-521 Chemicals and Materials
Report of Technical Working Group 1 of the Critical Technologies Project (U)
John E. Hove, Chairman

Study S-522 Transportation
Report of Technical Working Group 2 of the Critical Technologies Project (U)
Volume I
Volume II: Intelligence Assessments of Adversary Capability
Frederick R. Riddell, Chairman

Study S-523	Telecommunications Report of Technical Working Group 3 of the Critical Technologies Project (U) Volume I Volume II: Appendix--Adversary Capability Thomas A. Prugh, Chairman Emil F. Paroulek, Deputy Chairman
Study S-524	Avionics, Navigation, and Naval Equipment Report of Technical Working Group 4 of the Critical Technologies Project (U) Volume I Volume II: Appendix B--Assessment of Adversary Capability for Inertial Equipment Lawrence R. Dausin, Chairman
Study S-525	Semiconductors and Electronic Components Report of Technical Working Group 5 of the Critical Technologies Project (U) Volume I Volume II: Intelligence Assessment John K. Boidock, Chairman*
Study S-526	Electronic Instrumentation Report of Technical Working Group 6 of the Critical Technologies Project (U) Volume I Volume II: Intelligence Assessment Edwin N. Myers, Chairman

*On leave from the Department of Commerce under the Intergovernmental Personnel Act mobility program.

Study S-527 Computers
Report of Technical Working Group 7 of the
Critical Technologies Project (U)
Volume I
Volume II: Adversary Capability
Thomas A. Prugh, Chairman

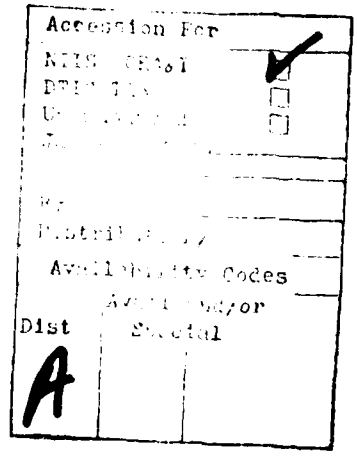
Supporting Papers

These papers report on related work performed in support of the project but addressing somewhat different topics.

Note N-878 Software Technology Transfer and
Export Control
Seymour E. Goodman et al.

Paper P-1548 The Role of DoD in Export Control as
Defined by the Export Administration
Act of 1979
Forrest R. Frank

Paper P-1549 Directed Energy
Edwin N. Myers



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EXECUTIVE SUMMARY

Introduction

The IDA Critical Technologies Project was undertaken by request of the Deputy Under Secretary of Defense, International Programs and Technology, in December 1979. The objective was to develop a list of recommended entries for the initial Militarily Critical Technologies List (MCTL), which the Export Administration Act (EAA) of 1979 required the Department of Defense (DoD) to publish in the Federal Register by October 1, 1980. Organized and managed by IDA, this effort was to be national in scope, making full use of the military, technical and intelligence resources of the military Services, U.S. industry experts, and the intelligence community, as available. Also, the effort was to make full use of information and expertise developed during the preceding three years of effort to develop the critical technologies approach to the export control of dual-use technology. At the same time, because of the rigid time constraints placed by law upon completion of this initial effort, certain compromises in scope and approach were recommended by IDA with concurrence by DoD to assure timely completion. In parallel with this IDA effort, there were other activities carried out by the Services or contractors to address issues or technology areas outside the specific scope of the IDA task. These efforts are not discussed in this report.

Limitations

The major compromises referred to above were:

1. IDA was given the flexibility by DoD to organize the project into technology areas best suited to the needs for effective management so long as uniform consideration was given to the entire range of technologies studied. As detailed later in this report, we chose to organize into seven technology areas, defined so as to be directly relatable to the State Department Technical Task Groups (TTGs) and the earlier industry associations' Critical Technology Expert Groups (CTEGs).

2. Three technology areas were excluded from the study because IDA felt it could not deal properly with their special expertise or information access requirements within the time frame of this study. These were photographic equipment, military equipment, and atomic energy.

3. Consideration was limited to technologies which support products on the *Commodity Control List* (CCL) for national security reasons. This served to sharply focus the effort, assure that the legal requirements of specificity could be met, and assure maximum relevance of the recommended entries to the basic issue underlying the EAA--the possibility of replacing export controls on some portion of the products on the CCL by corresponding controls on the underlying militarily critical technologies.

These compromises are explicit in the formal task order under which IDA agreed to undertake this project.

Objective

The basic objectives of the IDA Critical Technologies Project was then, within the foregoing constraints, to develop a list of recommended entries to the initial MCTL which the DoD was required by law to publish by October 1, 1980. Full support in the form of data and rationale was also to be provided for each such recommended entry.

As required by law, emphasis was to be given to:

(a) Arrays of design and manufacturing know-how,

(b) Keystone manufacturing, inspection, and test equipment, and

(c) Goods accompanied by sophisticated operations, application, or maintenance know-how,

which are not possessed by countries to which exports are controlled and which, if exported, would permit a significant advance in a military system of any such country. For this study, policy guidance from the DoD was to restrict our consideration to Bloc countries, especially the USSR.

It was also a specific requirement of the EAA that the list entries should be sufficiently specific to guide the determinations of any official exercising export licensing responsibilities.

Organization and Staffing

The overall organization of the DoD Critical Technologies effort is indicated in Fig. I-1. As shown, the military Services, intelligence community, and other agencies participated in several ways, simultaneously, through the DoD Steering Group, in the Mission Technology Task Force, and by direct participation in the IDA Critical Technologies Project. Overall policy guidance and coordination were effected by the Director, Technology Trade, Dr. Oles Lomacky. This report deals only with that portion of of the overall effort which was under IDA management.

The organization of the IDA Critical Technologies Project is indicated in Fig. I-2. Basically the effort consisted of a small, full-time resident team which carried out all project management and detailed technical direction. This team also organized and directed the activities of the seven Technical Working Groups (TWGs). Its members were carefully selected for

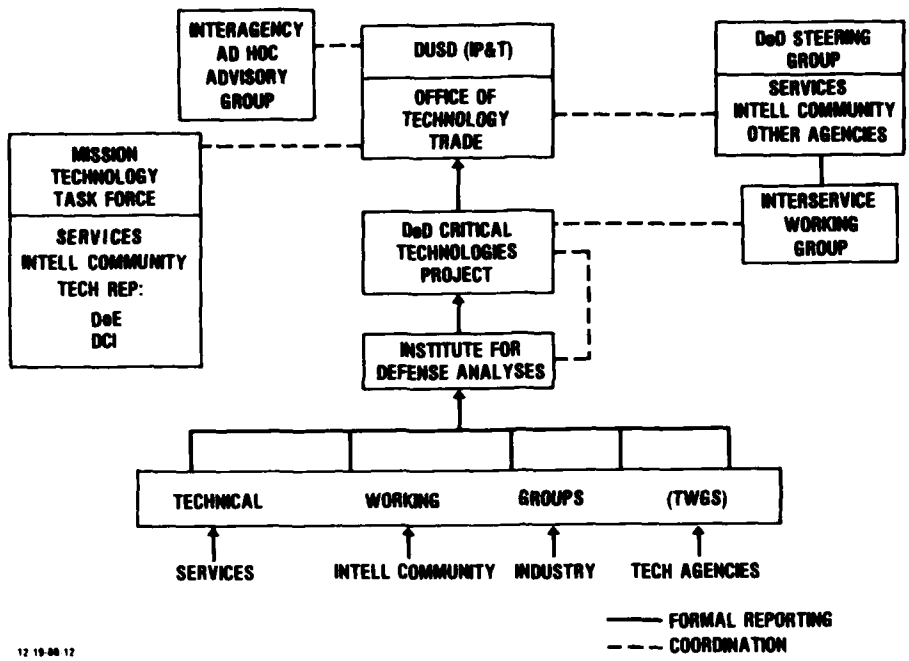

FIGURE I-1. Overall Project Organizational Structure

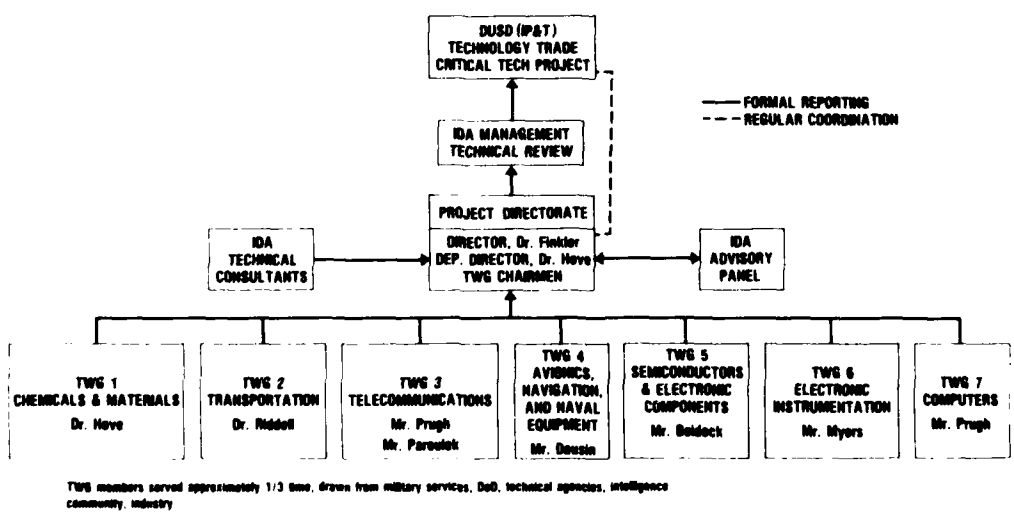

FIGURE I-2. IDA Critical Technologies Project

their broad experience in the pertinent technology areas, with emphasis on experience in technology transfer matters or in the relationship between technology and systems performance. Four of the TWG chairmen and deputy chairman were brought in from outside IDA on a term or consulting basis.

Working with industry and the Services, each of the TWG chairmen organized a team of experts from industry, the military Services, the intelligence community and other agencies to provide the broadest possible range of in-depth expertise on leading edge technologies, military use of advanced technologies and knowledge concerning Bloc capabilities. Each chairman was also assisted by expert consultants, resident part-time at IDA. Finally, a small amount of supporting effort was carried out by local companies on a subcontract basis. Strong support was provided by ODUSD (IP&T) in making these staffing arrangements. In addition, a large number of individuals within OSD, the Services, Defense agencies, other Government departments, and industry served in a liaison role to provide the fullest possible interchange of information and reports on progress.

The study effort was critically reviewed by the IDA Advisory Panel of senior outside experts at the beginning, middle and end of the project. These were individuals with high level technical management experience in government and/or industry, who had long familiarity with the complex problems of military R&D, technology transfer or assessment of adversary capabilities. Finally, an organizationally independent internal IDA technical reviewer was assigned to monitor quality and progress, reporting to the President, IDA.

A listing, which we hope is complete, of all significant technical participants is given in Appendix A. The total number is in excess of 300.

TWG Activities

Figure I-3 exhibits the schedule of activities for the task. The activities of the various TWGs began in February, in time-phased fashion, and continued through July. The typical program of activities for each TWG consisted of a series of six working group meetings at IDA lasting for three days each, spaced at four-week intervals. At each meeting there was presentation of work accomplished since the prior meeting, intensive discussion of technical issues at hand, and determination and assignment of work to be accomplished for presentation at the next meeting. Members were expected to contribute about one-third of their time between meetings to these activities and to make full use of available support from their home organizations. These responsibilties were taken quite seriously so that the total amount of effort, by military Services and industry alike, far exceeded that directly supported by the Project, about 10 man-years. Thus, the Critical Technologies Project was organized as an orderly process of utilizing uniformly the best in-depth judgments of the U.S. community of military, intelligence and technical experts to identify the candidate militarily critical technologies.

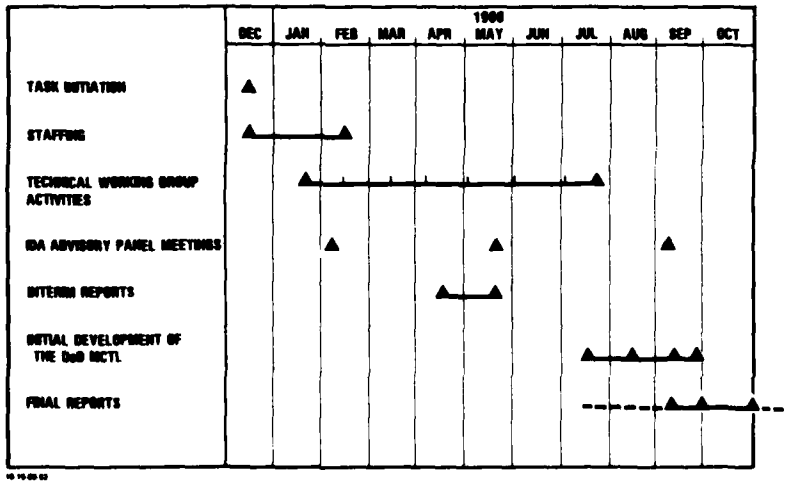

FIGURE I-3. Task Activities

Table I-1 shows the resource material available to the TWGs resulting from prior DoD and interagency activities relating to export control or prior work on the development of the critical technologies approach. The availability of this extensive source material allowed the project to get under way expeditiously. It was also very useful in identification of available experienced experts to participate in the study.

TABLE I-1. RESOURCE MATERIAL FOR TWGs

- DEFENSE SCIENCE BOARD REPORT OF 1976
- PRIOR OSD AND SERVICE TECHNOLOGY COMPILATIONS
- CTEB REPORTS
- TAC REPORTS
- 1979 TTB REPORTS
- COCOM LIST
- COMMODITY CONTROL LIST
- NAVY TECHNOLOGY STUDY
- AIR FORCE STUDY
- DRAFT CTBB REPORT, MARCH 1979

Table I-2 displays the links between the various technical groups, critical technology lists, and CCL items and shows how they relate to the TWGs.

In July DoD finalized its policy decisions as to the scope and structure to be adopted for the published MCTL. It was to include all of the technology areas covered by the IDA task as well as some technologies not directly related to the CCL or not covered by the TWGs. These additional technologies were identified by the Services. Also, the decision was made to organize the MCTL by the 18 critical technology areas earlier identified by the DoD and to structure the format precisely to the three technology categories specified in the EAA. The organization of the TWG-recommended entries was by working group and the structure was significantly different for technical reasons.

TABLE I-2. TWG LINKS TO PAST EFFORTS

TWG	TTG	CTEG	TAC	CCL ITEMS DUAL-USE PRODUCTS ONLY (HARDWARE OR SOFTWARE)	MILITARILY CRITI (LIST
1 Chemicals and Materials	A Metal Working Machinery B Chemicals C Metals	4 Structures, Materials and Processes	Numerically Controlled Machine Tools	1072, 1075, 1091, 1093, 1110, 1118, 1129, 1131, 1133, 1142, 1145, 1203, 1208, 4203, 1305, 13XX, 13YY, 2319, 1352, 1357, 1631, 1635, 4635, 1648, 1649, 1658, 1661, 1670, 1671, 1673, 1701, 1702, 1715, 1746, 4746, 1754, 1755, 4755, 1780, 1763, 1781, 1801	9 Deep Drawn Thin-Walled Metal Parts Design 10 Fracture Control Design Process 14 Composite Filament Winding 15 Diffusion Bonding, including Titanium 16 Electrocatalysis: Chemical Modification of Electrodes 17 Electroforming 18 Electrostream Hole Drilling 20 High Energy Rate Forming 21 High Performance Welding, including Explosive Welding 22 High Precision Manufacture of Large Pressure Vessels 23 High Vacuum Processes 24 Hot Isostatic Processing 25 Inspection of Advanced Composite Structures 26 Non-Destructive Evaluation Technology 27 Numerical Control of Machine Tools, including Adaptive 28 Plasma Spraying 30 Thixocasting and Rheocasting of Ferrous Materials
2 Transportation	D Transportation	8 Jet Engines 9 Commercial Aircraft		1080, 1081, 1086, 1088, 1361, 1362, 1416, 1431, 4431, 4409, 1460, 4460	6 Advanced Airfoil and Three-Dimensional Wing Design 8 Control Configured Vehicle (e.g. Fly-by-Wire 12 Airframes (e.g. Wide Body Transports) 107 Structural Analysis and Integrity Assessment Systems Using Microprocessors 110 Vibration Test Equipment 120 Normal-Conducting Homopolar Electrical Machinery 122 Segmented-Magnet Motors and Generators
3 Telecommunications	E Telecommunications		Telecommunications Equipment	1353, 1517, 1518, 1519, 1520, 1526, 1528	50 Solid-State Transmitters and Frequency Amplifiers 53 Wide-Band, Low-Noise Receivers 82 Fiber Optics Integrated Optics 86 Optical Fiber Cable Assemblies, Devices and Fiberguide
4 Avionics, Navigation and Naval Equipment	F Avionics	1 Array Processors 2 Acoustic Arrays		1418, 1485, 1501, 1502, 1510, 1514, 1561, 1585, 1759	1 Acoustic Deplorers 2 Acoustic Propagation 3 Acoustic Reception (Including Towed Arrays) 4 Acoustic Transmission (Including Transducers) 5 Deep Ocean (RUWS-SWP) 11 Platform Stabilization 13 Beamsteer Rotors 29 Replicated Optics 47 Conformal Antenna Arrays 48 High Dynamic Range Receivers 49 High-Performance Clutter Rejection Radar 51 Specialized Space Antennas
5 Semiconductors and Electronic Components	G Semiconductor Equipment I Electronic Components	6 LSI IC Production 7 Infrared Detection	Semiconductors	2120, 1205, 1355, 1537, 1542, 1544, 1545, 1547, 1548, 1549, 1553, 1555, 1556, 1558, 1559, 1580, 1584, 1586, 1587, 1588(11), 1757, 4757	19 Glass Ceramic Applications 37 Fiber Optics Materials 40 Optical Thin Film Materials 42 Polymers (Including Piezoelectric and Pyroelectric 44 Radiation Detection Materials 45 Solid-State Microwave Device Materials 67 Infrared Detectors and Materials (Including Hg0.8 Cd0.2 Te) 68 Intensified Array Detectors 73 Charge-Coupled Device Signal Processing and Imaging 74 Gallium Arsenide Devices (Including Microwave FPAs) 75 Large Scale Integrated Circuits (Including Microprocessors, High Performance NL Schottky TTL) 76 Metal Oxide Threshold Switches (MOTS) 77 Millimeter Wave Devices (e.g. 35 and 95 GHz) 78 Solid State Light Modulators 79 Solid State Microwave Devices (Including Diodes, Silicone Bipolar Amplifiers and ICs)
6 Electronic Instrumentation	H Electronic Instrumentation	5 High Energy Lasers	Electronic Instrumentation	1356, 1516, 1521, 1522, 4522, 1529, 1531, 1533, 1541, 1588, 1572, 1584, 4584, 1585, 4585, 4588	94 Photo-Recording Materials 103 High-Density Optical Recording 84 High-Power Optics 92 High-Performance A-D Converters 93 High-Performance Cathode Ray Tubes 97 Ultrastable Oscillators 99 Electron Accelerators 101 High-Precision Clocks and Frequency Standards 104 Remote Sensing 105 Seismic Intrusion Sensors 108 Ultra High-Speed Photography
7 Computers	K Computers	3 Computer Networks	Computer Systems Computer Peripherals, Components & Test Equipment	1358, 1585**, 1572, 1588, 4588	Computer Aided Design, Other Than for ICs and Machine Tools) 94 Artificial Intelligence Software 96 Beamforming Communication 98 Computer Disc Systems 99 Distributed Data Base Systems 99 Large Memory Storage (e.g. 10^{15} Bits

8 14 80 1

TWG LINKS TO PAST EFFORTS

CCL ITEMS USE PRODUCTS (HARDWARE OR SOFTWARE)	MILITARILY CRITICAL TECHNOLOGIES (LIST OF 138)	AREAS OF MILITARILY CRITICAL TECHNOLOGIES (LIST OF 18)* *Areas 16 & 18 not covered by direction	COMMENTS
1075 1091 1093 1110 1129 1131 1133 1142 1203 1206 4203 1305 13YY 2319 1352 1357 1635 4635 1648 1649 1661 1670 1671 1673 1702 1715 1746 4746 1755 4755 1760 1763 1801	6 Deep Drawn Thin-Walled Metal Parts Design 10 Fracture Control Design Process 14 Composite Filament Winding 15 Diffusion Bonding, including Titanium 16 Electrocatalysis, Chemical Modification of Electrodes 17 Electroforming 18 Electrostream Hole Drilling 20 High-Energy Rate Forming 21 High-Performance Welding, including Explosive Welding 22 High-Precision Manufacture of Large Pressure Vessels 23 High Vacuum Processes 24 Hot Isostatic Processing 25 Inspection of Advanced Composite Structures 26 Non-Destructive Evaluation Technology 27 Numerical Control of Machine Tools, including Adaptive 28 Plasma Spraying 30 Thixocasting and Rheocasting of Ferrous Materials 31 Vacuum Casting, Especially Air Cooled Turbine Blades 32 Vapor Deposition (Physical and Chemical) 33 Amorphous Metals 34 Boron Fibers 35 Corrosion Erosion Resistant Coatings 36 Cubic Boron Nitride for Tooling 38 High Temperature Coatings for Superalloys and Titanium 39 Metal-Matrix Composites (including Carbon-Carbon, Organic 41 Polyimides, including Kevlar 42 Polymers (including High Temperature Elastomers) 43 Powder Metallurgy (e.g. High Cooling Rate) 46 Ultrahigh Carbon Steels (e.g. Superplasticity) 89 Air Plasma Spray Technology 126 Photoassisted Electrochemical Cells 137 Polymeric Superconductors 138 Uncooled Mirror Materials	5 Materials Technology 17 Chemical Technology	Original CTEG Group was on Diffusion Bonding Only
1081 1086 1088 1361 1416 1431 4431 4409 4460	6 Advanced Airfoil and Three-Dimensional Wing Design 8 Control Configured Vehicle (e.g. Fly-by-Wire) 12 Airframes (e.g. Wide Body Transports) 107 Structural Analysis and Integrity Assessment Systems Using Microprocessors 110 Vibration Test Equipment 120 Normal-Conducting Homopolar Electrical Machinery 122 Segmented-Magnet Motors and Generators 123 Centrifugal Compressors for Small Turbine Engines 124 Closed-Cycle Brayton Turbine 127 Photochemical Enhancement in Airbreathing Engines 128 Propulsion Controls, Materials and Systems 131 Turbojet Engines (e.g. Composite Materials, Polyimides, Bearings) 133 Superconducting Electrical Machinery	12 Vehicular Technology	
1517 1518 1519 1520 1528	50 Solid-State Transmitters and Frequency Amplifiers 53 Wide-Band, Low-Noise Receivers 82 Fiber Optics Integrated Optics 86 Optical Fiber Cable Assemblies, Devices and Fiberguide 57 Computerized Exchange Switching (including Packet Switching)	9 Telecommunications Technology	
1485 1507 1502 1510 1561 1585 1758	1 Acoustic Displays 2 Acoustic Propagation 3 Acoustic Reception (including Towed Arrays) 4 Acoustic Transmission (including Transducers) 5 Deep Ocean (RUWS SWP) 11 Platform Stabilization 13 Beamingless Rotors 29 Replicated Optics 67 Conformal Antenna Arrays 68 High Dynamic Range Receivers 69 High-Performance Clutter Rejection Radar 51 Specialized Space Antennas 52 Synthetic Aperture Radar 89 Low Light Level Imaging 70 Tunable IR Filters (Acousto-Optical or Electro-Optical) 71 Wide Angle, Narrow Band Filters 81 Adaptive Optics 90 Coherent Microwave Memory Technology 100 Gravity Gradiometers 102 Inertial Navigation Systems (including Gyro and Accelerometers) 116 Laser Gyro Technology (including Ring Laser Gyros) 119 High Magnetostriction Rare Earth Alloys	10 Communication, Navigation, Guidance and Control Technology 14 Sensor Technology 15 Undersea Systems Technology	
1205 1356 1537 1542 1545 1547 1548 1549 1566 1566 1568 1568 1584 1586 1587 1588(11) 4757	19 Glass Ceramic Applications 37 Fiber Optics Materials 40 Optical Thin Film Materials 42 Polymers (including Piezoelectric and Pyroelectric) 44 Radiation Detection Materials 45 Solid-State Microwave Device Materials 47 Infrared Detectors and Materials (including Highly Resistivity Silicon) 88 Integrated Array Detectors 73 Charge-Coupled Device Signal Processing and Imaging 74 Gallium Arsenide Devices (including Microwave FPs) 75 Large-Scale Integrated Circuits (including Microprocessors, High Performance IIL, Schottky TTL) 76 Metal Oxide Threshold Switches (MOTS) 77 Millimeter Wave Devices (e.g. 35 and 98 GHz) 78 Solid-State Light Modulators 79 Solid-State Microwave Devices (including Diodes, Silicone Bipolar Amplifiers and ICs) 80 Surface Acoustic Wave Devices and Technology 85 Infrared Focal Plane Arrays 88 Advanced Microwave Transmission Line Components (including Microwave Tubes) 94 High Performance Traveling Wave Tubes 95 Millimeter Wave Tubes (e.g. 35 and 95 GHz) 96 Phase Control Components 98 Flash Radiography 103 Nondestructive Thin-Film Measurement 117 Solid-State Laser Diodes (Injection Laser Development) 121 Rare Earth Alloy Permanent Magnets 125 Electrolyte Battery Developments (including Lithium Inorganic and Low Temperature Solid) 134 Superconducting Sensors and Oscillators (including Josephson Tunnel Junction) 135 Superconducting Magnetometer Technology (including Quantum Interference Devices)	7 Semiconductor and Electronic Components Technology 11 Microwave Technology	
1516 1521 1522 4522 1531 1533 1541 1588 1584 4584 1585 4585	84 Photo-Recording Materials 83 High-Density Optical Recording 84 High-Power Optics 92 High-Performance A-D Converters 93 High-Performance Cathode Ray Tubes 97 Ultrastable Oscillators 99 Electron Accelerators 101 High-Precision Clocks and Frequency Standards 104 Remote Sensing 109 Seismic Intrusion Sensors 108 Ultra-High Speed Photography 109 Very Wide-Band Tape Recorders 111 Coherent Sources with Wavelengths Shorter Than 1000 Angstroms 112 Electrical Excitation Technology for Lasers 113 FAR IR Lasers (More than 58 Micrometers) 114 Frequency Multipliers for Infrared Lasers 115 High-Energy Lasers (including Electrical Discharge, Gas Dynamic and Chemical) 118 X-Ray Laser Technology 136 Cooled Metal Mirror Fabrication	8 Instrumentation Technology 13 Optical & Laser Technology 6 Directed Energy Technology	
1565** 1572 1588 4580	7 Computer Aided Design (Other Than for ICs and Machine Tools) 54 Artificial Intelligence Software 56 Biorybernetic Communication 58 Computer Disc Systems 59 Distributed Data Base Systems 60 Large Memory Design (e.g. 10^{15} Bits) 89 Memory Technologies (including Bubble Memory and Logic, High Density Cores, Rapid Access Erasable) 81 Natural Language Communications with Computers 82 Optical Computing 83 Photo Interpretation by Computers 85 Processor Architecture 88 Speech Processing Technology 87 Plasma Displays 91 Fast Fourier Transform Processors	1 Computer Network Technology 2 Computer Technology 3 Software Technology 4 Automated Real-Time Control Technology	**Communication switching aspects covered by TWG 3

The merging of the Service and the then available IDA inputs was carried out in a series of intensive discussions led by IP&T and Service technical personnel with the support of the IDA TWG chairmen during early August to produce the draft MCTL by August 8. After DoD review and a later draft, DoD coordination of the MCTL and publication of its table of contents was accomplished by October 1, 1980. Security review considerations have delayed publication of the actual list.

The IDA report on this project deals only with work actually accomplished by IDA. To facilitate the use of the supporting analyses in the TWG reports by licensing officers and others, a cross-reference list has been prepared, for attachment to the MCTL and appropriate IDA reports. This cross-reference list indicates for each entry in the MCTL where supporting analysis may be found in the TWG reports, if it was within the scope of IDA effort. A similar cross-reference from the CCL to the MCTL has also been prepared. These cross-reference lists are given here in Appendices B and C, and are also included in the TWG reports.

Objectives, Terms, and Procedures

Examining "technology" to see what in it is critical to a military system and what is not must be a strictly disciplined process from the very beginning unless an inordinate amount of time is on hand. For this task, the time limit was severe. The approach, therefore, was to take every advantage of the information and experience that had been gathered over decades in COCOM negotiations, and over the last three or four years in DoD examinations of significant and critical technologies.

Every bit as important, but perhaps more difficult, the project had to come to early agreement on definitions of terms used. Because the terms and concepts involved have broad general meanings and are used in many different ways to suit

many different situations, they are imprecise. It was necessary for the TWGs to agree on the same specific meaning for the terms early in their work and stay with these definitions all the way through. While some were refined with experience, most stayed firm. They had to be useful for the analysis process as well as reasonably consistent with prior available literature and with the provisions of the EAA.

The judgmental analysis went through stages of selecting significant technologies, determining their military utility, and adversary capability, so as to arrive at a militarily critical technology and associated transfer mechanisms. Also, to the extent data were readily available, assessment of foreign capability was made and reported. Assessment of foreign availability within the meaning of the EAA was not addressed by the TWGs.

With regard to both adversary and foreign capability assessments, it should be emphasized that the data were generally incomplete. Furthermore, it should be pointed out, in the context of the EAA, that while adversary capability is clearly a component of the definition of militarily critical technology, foreign availability is not. Rather, it would appear from the EAA that assessment of foreign availability (which includes consideration of capability to develop and produce in quantity and quality as well as national willingness to export) is a factor to be taken into account by the Secretary of Commerce or the President in determining which goods or technology shall be subject to export controls, i.e., included in the CCL. Thus, a distinction is made between the MCTL, which is not a control list, and the CCL, which is. In this study, foreign capability assessment is given as a best judgment on the part of the TWGs from information available to them and for the information of licensing officers. It is not and does not imply an assessment of foreign availability. Note that the EAA requires DoD to provide such information, if available.

For specificity in the analysis, the technologies assessed are divided into three stages of development, production, and utilization.

The elements of militarily critical technology so selected were then aggregated for presentation as arrays of technical information and know-how, keystone equipment, keystone materials, and goods accompanied by sophisticated technical information and know-how.

The origin of the latter set of terms lies in the Bucy Report, the Sec Def Policy Memorandum of 26 August 1977, and in the EAA. Aggregation of the critical technologies into the previously underlined categories provides a form which might lend itself to specification and control, which is the ultimate intended usage of the MCTL.

Definitions of Terms

Militarily Critical Technology--Technology not possessed by our principal adversaries that specifically contributes to the superior characteristics (performance, reliability, maintainability, and cost) of a military system, a significant component thereof, or a related strategic product of any such adversary.

Terms Used in The Assessment of Technology

Significant Technology--Technology that specifically contributes to the superior characteristics (e.g., performance, reliability, maintainability, cost) of a system, a significant component thereof, or a related product.

Military Utility*--The specific contribution of a technology to the superior characteristics (e.g., performance, reliability, maintainability, cost) of a military system, a significant component thereof, or a related strategic product.

*Some TWGs found the information on the military utility of a technology to the Soviet Union insufficient to support judgment of its value and used as a surrogate military utility to the U.S.

Foreign Capability*--The mastery or ability to effectively apply or produce a significant technology possessed by organizations outside the United States but not including those of our principal adversaries.

Adversary Capability--The mastery or ability by our principal adversaries to effectively apply or produce a significant technology from indigenous sources.

Transfer Mechanisms--Any means, whether document, equipment, or activity, through which the substance of a militarily critical technology can be conveyed.

Terms Used in Describing Significant Stages of Technology

Technology--The process of development, production, and utilization that translates an application concept into a useful product. Technology consists of technical information and know-how (including technical data and computer software), and the equipment and materials necessary to effectively apply them. Note that technology does not include the research or store of scientific knowledge on which the application concept is based, nor the end useful product; however, such useful products as tools, for example, may be part of the technology to make other products.

Development--The process of design, fabrication, and experimental work that translates an application concept into a set of specifications, models, and design data necessary for the effective production of a product.

Production--The process of production design, manufacture, inspection and test that translates specifications and design data into a serially produced product meeting acceptable quality standards.

Product Utilization--The process of application, operation, and maintenance (including reconstruction) that translates a product into a useful capability for meeting a need.

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*In contrast, foreign availability in the context of the EAA would be the availability without restriction to principal adversaries from sources outside the United States of significant technologies in significant quantity and comparable quality to that available or produced in the United States.

Terms Used in Aggregating Technology Elements

Arrays of Technical Information and Know-How (including Arrays of Design and Manufacturing Know-How)--The interrelated collection and organization of services, processes, procedures, specifications, data, criteria, and training aids and/or instructions which individually may or may not be significant but because of their mutual effect on each other must be specified and mastered as a group to achieve a significant development, production, or utilization purpose.

Keystone Equipment (including Keystone Manufacturing, Inspection, and Test Equipment)--Equipment specifically necessary for the effective application of significant arrays of technical information and know-how.

Keystone Materials--Materials specifically necessary for the effective application of significant arrays of technical information and know-how.

Goods Accompanied by Sophisticated Technical Information and Know-How (including Operation, Application, or Maintenance Know-How)--Goods for whose utilization the provision (disclosure) of significant arrays of technical information and know-how, and/or keystone equipment or materials is essential.

To define a technology element too broadly would place so much under the umbrella of "significance" as to render it unworkable. To define a significant technology element too narrowly would run the risk of missing too much. Mindful that "significance" was limited to the ability to make a concrete product, not simply understanding how to do it in principle, each TWG broke down "making something" into the three stages of: development, production, and product utilization.

As an indication of the level of detail produced in the project, Table I-3 presents an example of the elements of Technology. Every attempt was made to consider each element of the middle level of aggregation. The many elements in the third and lowest level of aggregation were used primarily as a check list.

TABLE I-3. EXAMPLE OF ELEMENTS OF TECHNOLOGY

DEVELOPMENT

Design

Requirements & Criteria
Designs, Analysis, Selections & Data Base
Material, Component, Assembly & Product Specifications
Procedures & Processes & Their Specifications
Design, Analysis, Simulation and CAD Software
Software Design Tools
Training

Fabrication

Demonstration, Engineering & Prototype Models
Specialized Fabrication & Test Equipment
Materials, Components & Assemblies
Fabrication Procedures & Processes

Experimental Work

Experiment Design Criteria & Specifications
Materials, Components & Assemblies
Experimental, Collection & Test Equipment
Procedures & Software for Operating Experimental Equipment
Data Collection & Reduction Software
Generated Data Base

PRODUCTION

Production Design

Requirements & Criteria
Designs, Analysis, Selections & Data Base
Production Drawings
Manufacturing, Inspection & Test Equipment Specifications, Fabrication & Adaption
Materials, Components, Assembly & Product Specifications
Personnel Selection
Work Flow & Materials Handling Design
Facilities Preparation
Production & Inventory Control Procedures & Software

Manufacturing

Processes & Procedures
Manufacturing Equipment, Tools, Jigs & Fixtures
Software for Operating Manufacturing Equipment
Materials, Components & Assemblies
Personnel Training & Documents

Inspection and Test

Quality Assurance Processes, Procedures & Standards
Inspection & Test Equipment, Tools, Jigs & Fixtures
Software for Operating Inspection & Test Equipment
Standards Laboratory for Inspection & Test Equipment
Personnel Training & Documentation

PRODUCT UTILIZATION

Application

Requirements & Criteria
Sales Notes, Specifications & Proposals
Designs, Analysis & Selections for Intended Use
Software for Design, Analysis & Selection
Facility Design & Preparation
Personnel Selection

Operation

Operating Procedures
Operating System & Application Software
Personnel Training & Documents

Maintenance

Installation & Maintenance Processes, Procedures & Documentation
Inspection & Test Equipment
Software for Operating Inspection & Test Equipment
Software for Product Self-Diagnosis
Personnel Training & Documents

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When the above process of analysis was complete, the results were aggregated in the manner indicated in the EAA for potential inclusion in the CCL as:

- Arrays of technical information and know-how
- Keystone equipment
- Goods accompanied by sophisticated technical information and know-how.

The result of the above process was the identification of some one thousand specific militarily critical technologies.

The requirement of sufficient specificity in the descriptors for licensing purposes, together with the military criticality requirement mitigated against any effort to reduce this list to a small number.

Because of the diverse nature of the militarily critical technologies, it turned out that the most effective transfer mechanisms were not the same in all cases. Therefore, in each case the TWG made a collective best judgment as to which transfer mechanisms were most effective and should be given first priority if controls were to be implemented. See Table I-4. The reasoning in each case is given in the TWG reports.

Operation of the Technical Working Groups

Each working group basically had the same initial input instructions. A set of CCL items were assigned and the TWG was asked to identify the significant underlying developmental, production and utilization technologies for each item and to evaluate their military utility and adversary capability. A similar request was made for assigned technologies previously identified by the DoD efforts (including those of the CTEGs).

However, the method of operation for each TWG tended to differ somewhat from the others. While partly influenced by the chairmen's individual tastes, these differences were mainly due to a variety of intrinsic differences between the seven technology areas. Thus, TWG 1 (Materials and Chemicals) had

TABLE I-4. TECHNOLOGY TRANSFER MECHANISMS LISTED IN DESCENDING ORDER OF EFFECTIVENESS

JOINT DEVELOPMENT, PRODUCTION, AND DISTRIBUTION PROJECTS

- Between Western and Communist Organizations
- National Bilateral Projects or Multinational Projects

PLANTS AND KEYSTONE EQUIPMENT WITH TECHNICAL ASSISTANCE

- Negotiations, Visits, and Sales Support
- Technical Support and Training

STAND-ALONE KEYSTONE EQUIPMENT WITH TECHNICAL ASSISTANCE FOR OPERATION

- Negotiations, Visits, and Sales Support
- Proprietary Information

LICENSES WITH TECHNICAL SUPPORT

- Licenses for Potential Products or Processes
- Licenses for Processing Know-How

CONTRACTUAL SERVICES (Independent of Sales)

- Technical Advisors and Consultants
- Tutorial Services

JOINT RESEARCH PROGRAMS

TRAINING AND EDUCATIONAL PROGRAMS (Independent of Sales)

- Programs in the U.S.
- Programs outside of U.S.

TECHNICAL VISITS AND DISCUSSIONS (Independent of Sales)

- Visits in the U.S.
- Visits outside of U.S.

SALES OF PRODUCT THAT PROVIDES SIGNIFICANT DISCLOSURE OF:

- Technical Information on Designs and Materials
- Technical Information on Processing or Fabrication Procedures

PUBLIC INFORMATION

- Literature, Documents, and Presentations
- Technical Information Services

SALES OF PRODUCT THAT *DO NOT* PROVIDE SIGNIFICANT DISCLOSURE OF TECHNICAL INFORMATION

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to deal, say, with the technology of making and using a commodity such as steel alloys or, as another example, the technology of manufacturing and using numerical-controlled machinery. These particular items can be used for just about anything and the evaluation of military utility entailed broad aggregation of users, but the technology itself was quite narrowly defined. On the other hand, TWG 2 (Transportation) had to deal, say, with the technology of design, production, and utilization of an aircraft. Even excluding avionics (which is in the province of another working group), this is a very complex system and it was essential to first break it down into subsystems, subassemblies, and components. Because there is such a large number of these parts, it was simply not feasible to analyze each one in detail and major subjective decisions had to be made early in the game as to which parts really were the most significant. Validity was given to these decisions by virtue of the best pooled experience of the various government and industrial members of the working group. Having identified a more tractable number of subassemblies or components, the process of identifying the critical technologies underlying these products could take place by the general methodology used by all TWGs. TWG 6 (Instrumentation) found that the utility of its elements depended on how and where they are used. There is nothing critical or noncritical about an oscilloscope, say, by itself; it depends on what kind of a larger system it could be part of, or used to test, and what characteristics or functionality it can contribute to that system. Because of the pervasiveness of their use, computers (TWG 7) had to be analyzed with all of the above techniques, aggregation, disaggregation, and the nature of the larger system of which computers were a part.

Details of how each working group did its job are given in the individual reports and will merely be touched on here.

TWG 1 (Chemicals and Materials) met each month as a unit to discuss and evaluate the results of each of the homework assignments given to specific individuals. Subgroups were not used since the materials, processes, and equipment on the agenda were all pretty generic and discussions with as broad a group as possible were considered most useful.

TWG 2 (Transportation) divided the transportation areas largely into the three subareas of aircraft and helicopters, maritime vehicles, and gas turbine engines. Three working groups were formed to analyze these subareas, which overlapped some but not very extensively. The three groups generally met together for special occasions only, such as intelligence briefings.

TWG 3 (Telecommunications) had a very late start due to difficulties in obtaining a chairman. Thus, it was only able to cover the areas of switching, modems and multiplexers, which were the areas given the highest priorities by the group.

TWG 4 (Avionics, Navigation, and Naval Equipment) largely was composed of three separate working groups, one on inertial equipment, one on avionics and radar systems and one covering acoustic systems, deep submersibles and syntactic foam. This TWG was quite fluid with subgroups formed for a special purpose and then disbanded. The subgroup on acoustics and submersibles did not meet often as an entity, but rather in a number of smaller meetings.

TWG 5 (Semiconductors and Electronic Components) divided into two separate subgroups, one on semiconductors and one on components. The semiconductor subgroup made a special trip to visit the Stanford Microelectronics Laboratory for a day and certain members of the subgroup made a visit to one of the Soviet Bloc countries to get first-hand information on adversary capability.

TWG 6 (Electronic Instrumentation) was quite fluid in its industrial membership, bringing in various experts to meetings depending on the subject being covered. The analyses of directed energy technologies were not done by the working group, per se,

but were performed entirely by the Air Force Weapons Laboratory which included parts of the CTEG report on high-energy lasers.

TWG 7 (Computers) had an especially difficult organizational problem due to the breadth and complexity of the subject which ranged from system development down to individual components and devices. However, the situation was aided by the existence of very good prior work such as the CTEG report on computer networks.

Results

The results of the activities of the Critical Technologies Project are all presented in one or more of the IDA Report, Studies, and Papers which constitute the written product of the IDA task.

TWG Reports: The results of each TWG study are published as a complete, stand-alone report which contains the structured compilation of the recommended militarily critical technologies, together with the supporting rationale for TWG judgments of degree of military utility, adversary capability and effectiveness of the various technology transfer mechanisms. Following policy guidance received from DoD, TWG judgments of the relative military criticality of the various technologies are not given in the published reports although it is self-evident that such judgments must ultimately be made. The rationale also includes judgments of foreign capability and the evidence for such judgments.

Each TWG report also presents the specific methodology used by it to carry out its analysis. As indicated previously, these varied substantially from one another.

Supporting Papers

Software Technology Transfer and Export Control

This paper first addresses the issues and problems faced when dealing with computer software in the export arena. What constitutes software know-how and how it is transferred are then analyzed. The paper concludes that one of the most critical technologies is that which is required for the successful development and maintenance of large software programs.

The Role of DoD in Export Control as Defined by the Export Export Administration Act of 1979

This paper reviews the evolution of the Export Administration Act of 1979 and the provisions contained therein for the control of exports of goods and technology from the U.S. in order to maintain or enhance U.S. national security. The paper then discusses possible uses of the militarily critical technologies list by different constituencies including the Congress, the Executive Branch, industry, and foreign governments. Finally, the paper identifies areas on which the Defense Department may wish to seek further guidance or clarification in statute and also identifies additional areas for further inquiry and study.

Directed Energy

Directed energy technology relates to the production of high energy beams consisting of infrared photons or atomic particles and the means for directing them to distant points. The primary purpose is the destruction of a military target. This paper reviews the critical technology which is the key to the performance of gas dynamic, chemical and electrical lasers and particle accelerators capable of producing high energy beams of potential military interest.

APPENDIX A

MEMBERSHIP - IDA CRITICAL TECHNOLOGIES PROJECT

APPENDIX A

MEMBERSHIP - IDA CRITICAL TECHNOLOGIES PROJECT

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COMPUTERS, TWG 7

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APPENDIX B
CROSS-REFERENCE LIST:
MCTL TO IDA TWG REPORTS

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This cross-reference list contains five columns. Column 1 lists the MCTL number and column 2 the MCTL title as documented in the Draft DoD Militarily Critical Technologies List dated 1 October 1980.

The last three columns address the IDA reports on critical technologies. Column 3 lists the IDA Recommended Critical Technologies (labeled IDA CT) number and column 4 specifies the Technical Working Group (TWG) responsible for investigating the item. Column 5 notes the section number of the TWG report in which the particular technology is discussed.

In certain instances, the words "Not Covered" will appear across columns 3, 4, and 5. "Not Covered" means that IDA TWGs did not study the particular technology identified by the MCTL.

CROSS-REFERENCE LIST
MCTL TO IDA CRITICAL TECHNOLOGY (CT)

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
1.0	COMPUTER NETWORKS TECHNOLOGY			
1.1	Network Architecture	7.1.4	7	3.8
1.2	Implementation	7.1.5	7	3.8
2.0	COMPUTER TECHNOLOGY			
2.1.1	General System Architecture	7.1.1	7	3.5
2.1.2	Processor Architecture	7.1.2	7	3.6
2.1.3	Memory Hierarchy	7.1.3	7	3.7
2.2.1	Computer Hardware Development	7.2.1	7	4.6
		7.2.2	7	4.7
2.2.2	Computer Hardware Production	7.2.3	7	4.8
2.2.3	Computerized Manufacturing Control System (CMCS)	7.2.3	7	4.8
	Computer-Assisted Manufacturing (CAM)	7.2.4	7	4.9
2.2.4	Interconnections	7.2.5	7	4.11
2.2.5	Production Testing	7.2.6	7	4.12
2.2.6	Computer Cooling	7.2.7	7	4.13
2.2.7	Power Supply and Distribution	7.2.8	7	4.14
2.3.1	Computer-Assisted Servicing (CAS)	7.3.1	7	5.2
2.3.2	Computer System Configuration Management	7.3.2	7	5.3
2.3.3	Digital Computer Security	7.3.3	7	5.4
2.3.4	Computer-Assisted Training/Simulation	7.3.4	7	5.5
2.4.1	Semiconductor Logic and Memory Assembly	7.5.1	7	7.6
2.4.2	Magnetic Core Memory	7.5.2	7	7.7

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
2.4.3	Josephson Junction	7.5.3	7	7.8
2.4.4	Charge-Coupled Device (CCD) Memory	7.5.4	7	7.9
2.4.5	Magnetic Bubble Logic and Memory	7.5.5	7	7.10
2.4.6	Magnetic Cross-Tie Memory	7.5.6	7	7.11
2.4.7	Plated Wire Memory	7.5.7	7	7.12
2.4.8	Microprocessor	7.5.8	7	7.13
2.5.1.1	Magnetic Disc Read/Write Head	7.6.1	7	8.8
2.5.1.2	Magnetic Disc Recording Media	7.6.2	7	8.9
2.5.1.3	Winchester Disc	7.6.3	7	8.10
2.5.1.4	Flexible Disc Drive	7.6.4	7	8.11
2.5.2.1	Conventional Magnetic Tape Drive	7.7.1	7	9.6
2.5.2.2	Cartridge/Cassette	7.7.2	7	9.7
2.5.3.1	Electron Beam Memory	7.8.1	7	10.6
2.5.3.2	Optical Cryogenic Memory	7.8.2	7	10.7
2.5.3.3	Holographic/Laser Memory	7.8.3	7	10.8
2.5.3.4	Video Disc Digital Recording	7.8.4	7	10.9
2.5.3.5	Archival Magnetic Tape Memory	7.7.2	7	9.7
2.6.1	Alphanumeric and Graphic Terminal	7.9.1	7	11.2
		7.9.2	7	11.3
		7.9.3	7	11.4
		7.9.4	7	11.5
2.6.2.1	Digital Flat-Bed	7.10.1	7	12.2
2.6.2.2	Non-Impact Line Printer	7.10.2	7	12.3
2.7	Analog and Hybrid Computer	7.11	7	13.8
		7.12	7	14.8
2.8.1	Speech Processing	7.13.1	7	15.2
2.8.2	Artificial Intelligence	7.13.2	7	15.3
3.0	SOFTWARE TECHNOLOGY			
3.1.1	Software Life-Cycle Management	7.4.1	7	6.7
3.1.2	Software Library Data Base	7.4.2	7	6.8

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
3.1.3	Software Development Tools	7.4.1	7	6.7
3.1.4	Formal Methods and Tools for Developing Trusted Software	7.4.2	7	6.8
3.2.1	Maintenance of Large Software Product	7.4.1	7	6.7
3.3.1	Secure Software	7.4.2	7	6.8
3.3.2	Large Self-Adapting Software System	7.4.2	7	6.8
4.0	AUTOMATED REAL-TIME CONTROL TECHNOLOGY			
4.1	Utilization of Digital Processing	7.1.2	7	3.6
4.2	Analog and Hybrid Computing Technique	7.11	7	13.8
		7.12	7	14.8
4.3	Display	Not covered		
4.4	Related Software	7.4.1	7	6.7
5.0	MATERIALS TECHNOLOGY			
5.1.1	Magnetic and Amorphous Metals	1.2.1	1	4.2
5.1.2	Nickel-Based Alloys	1.2.9	1	4.5
				4.10
5.1.3	Titanium Alloys	1.2.2	1	4.6.1
5.1.4	High-Temperature Coatings for Superalloys and Titanium	1.2.3	1	4.6.2
		1.2.8	1	4.9
5.1.5	Niobium (Columbium) Alloys	1.2.4	1	4.7.1
5.1.6	Molybdenum Alloys	1.2.5	1	4.7.2
5.1.7	Tungsten Alloys	1.2.6	1	4.7.3
5.1.8	Casting and Coating of Intricate Hollow Superalloy Shapes	1.2.8	1	4.9
5.1.9	Plasma Spraying	1.2.17	1	4.18

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
5.1.10	Advanced Powder Metallurgy	1.2.9	1	4.10
5.1.11	Superplastic Forming/Diffusion Bonding (SPF/DB)	1.2.10	1	4.11
5.1.12	Titanium, Nickel and Iron Aluminides	1.2.16	1	4.17
5.1.13	Superconducting Materials	Not covered		
5.1.14	Pressure Pipe and Fittings	1.2.18	1	4.19
5.2.1	Fibers and Filamentary Materials	1.4.1	1	7.2
5.2.2	Filament Winding, Tape Laying and Interlacing	-	2	3.10.2
5.2.3	Advanced Organic Matrix Composites	1.4.2	1	7.3
5.2.4	Metal and Graphite Matrix Composites	-	1	7.4
5.2.5	Ceramics	1.5.2	1	8.3
		-	1	6.0
5.2.6	Superalloy Composites	-	1	7.5
5.3.1	Hot Isostatic Pressing (HIP)	1.2.11	1	4.12
5.3.2	High-Temperature Press	1.1.1	1	3.2
5.3.3	Isothermal Rolling Mill	1.1.5	1	3.7
				3.12
5.3.4	Isothermal Metal Working	1.2.15	1	4.16
5.3.5	High-Temperature Furnace and Coating Unit	1.1.6	1	3.8
5.3.6	Numerically Controlled Machine Tools	1.1.3	1	3.5
5.3.7	Precision Turning Machines	1.1.4	1	3.6
5.3.8	Spin- and Flow-Forming Machines	1.1.2	1	3.4
5.3.9	High Vacuum	-	1	3.11.2
			1	3.11.4
			1	3.11.5
5.3.10	Not Used	-	-	-
5.3.11	Laser Processing Technology	1.2.14	1	4.15

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
5.3.12	High Performance Welding	1.2.13	1	4.14
5.3.13	Fracture Analysis, Nondestructive Evaluation (NDE) and Control	1.2.12	1	4.13
5.3.14	Test Equipment for Integrated Structural Testing	Not covered		
6.0	DIRECTED ENERGY TECHNOLOGY			
6.1.1	High Energy Laser	6.8.2	6	11.1
6.1.2	Mirror and Optical Device	6.8.2	6	11.1
6.1.3	Beam Pointing and Control	Not covered		
6.1.4	Mounting Subsystem	Not covered		
6.1.5	Beam-Targeting Coupling	Not covered		
6.1.6	Beam Propagation	Not covered		
6.2.1	High-Current Particle Beam Generation	6.8.1	6	11.2
6.2.1.1	Post-Injection (Particle Beam Accelerator)	6.8.1	6	11.2
6.2.2	Short-Term Energy Generation Subsystem	6.8.1	6	11.2
6.2.3	Beam Propagation	Not covered		
6.2.4	Beam-Target Coupling	Not covered		
6.2.5	Beam Control Subsystem	Not covered		
6.2.6	Beam Neutralization	-	6	11.2
6.3	Microwave Energy Transmission	Not covered		
7.0	SEMICONDUCTOR AND ELECTRIC COMPONENT TECHNOLOGY			
7.1.1	Wafer Preparation	5.1.2	5	3.1.7.1
7.1.2	Epitaxy	5.1.3	5	3.1.7.2

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
7.1.3	Oxidation	5.1.4	5	3.1.7.3
7.1.4	Maskmaking	5.1.5	5	3.1.7.4
7.1.5a	Lithography-Resist Processing	5.1.6	5	3.1.7.5
7.1.5b	Lithographic-Wafer Imaging	5.1.6	5	3.1.7.5
7.1.6	Selective Removal	5.1.7	5	3.1.7.6
7.1.7	Diffusion/Implantation	5.1.8	5	3.1.7.7
7.1.8	Thin Film Deposition	5.1.9	5	3.1.7.8
7.1.9	Assembly	5.1.10	5	3.1.7.9
7.1.10	Testing	5.1.11	5	3.1.7.10
7.1.11	Facilities	5.1.12	5	3.1.7.11
7.1.12	IC Design	5.1.1	5	3.1.6
7.1.13	Hybrid Microcircuits	5.2	5	3.2
7.1.14	Microwave Microcircuits	5.3	5	3.3
7.2.1	Discrete Transistors	5.4.1	5	4.5
		5.4.2	5	4.6
7.2.2	Diodes	5.5.1	5	5.5.1
		5.5.2	5	5.5.2
7.2.3	Thyristors	5.9.1	5	9.5
		5.9.2	5	5.6
7.3.1	Semiconductor Detectors	5.6.1	5	6.5.1
		5.6.2	5	6.5.2
7.3.2	Photomultiplier Tubes	5.19	5	19.0
7.3.3	Image Intensifiers	5.18	5	18.0
7.3.4	Thermoelectric Coolers	5.16	5	16.0
7.4	Acoustic Wave Device	5.7	5	7.0
7.5.1	Magnetic Bubble Memories	5.8.1	5	8.1
7.5.2	Plated Wire Memories	5.8.2	5	8.2
7.5.3	Cross-Tie Memories	5.8.3	5	8.3
7.6.1	Ferrite Materials	5.11	5	11.0
7.6.2	Boundary Layer Monolithic Ceramic Capacitors	5.10	5	10.0
7.6.3	Quartz Crystals	5.12	5	12.0
7.6.4	Printed Circuit Boards	5.15	5	15.0

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
7.7.1	Superconducting Digital Components	5.13	5	13.0
7.7.2	Superconducting RF Components	Not covered		
7.7.3	Cryogenic Coolers	Not covered		
7.8.1	Bulk Indium Phosphide (InP)	Not covered		
7.8.2	Bulk Gallium Arsenide (GaAs)	Not covered		
7.8.3	Vapor Phase Epitaxy of In_{1-x} $Ga_xP_{1-y}ASy$ on InP	Not covered		
7.8.4	Lead Lanthanium Zirconium Titanate (PZLT)	Not covered		
7.8.5	Lead Zirconium Titanate (Pb (ZrTi) O_3 PZT)	Not covered		
7.8.6	MgO (Magnesium Oxide, Periclase)			
7.8.7	Thin Film Interference Coatings for Optics and Other Applications by Vacuum Deposition	Not covered		
7.8.8	Sodium and Potassium Halides (NaF, NaCℓ, KCℓ, KBr, etc.)	Not covered		
7.8.9	Thallium Bromoidiode ($TIBr_xI_{1-x}$, KRS-5)	Not covered		
7.8.10	Dehydrogen Phosphates (ADP, KDP, KD*P, CD*P, CD*A, etc.)	Not covered		
7.8.11	Bismuth Silicon Oxide (BSO, $Bi_{12}SiO_{20}$) Bismuth Germanium Oxide (BGO, $Bi_{12}GeO_{20}$)	Not covered		
7.8.12	Polyvalent Binary Fluorides (e.g., BaF_2, CeF_3, LaF_4, ThF_4, ZrF_4)	Not covered		
7.8.13	Yttrofluorides (e.g., $LiYF_4$, KY_3F_{10}, etc.)	Not covered		
7.8.14	Niobates and Tantalates (e.g., $LiNbO_3$, $LiTaO_3$, $KNbO_3$)	Not covered		

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
7.8.15	Neodymium Laser Hosts (especially YAG ($Y_3A_5O_{12}$), but also including $La_2Be_2O_5$, NdP_5O_{14}, $K_5NdLi_5F_{10}$, etc.)	Not covered		
7.8.16	Lanthanum Chloride Laser Materials ($LaCl_3:Pr^{3+}$, $:Er^{3+}$, etc.)	Not covered		
7.8.17	Mercury Cadmium Telluride (bulk and thin films)	Not covered		
7.8.18	Cadmium Telluride Crystals	Not covered		
7.8.19	Lead Telluride (PbTe)	Not covered		
7.8.20	Epitaxial Lead Tin Telluride and Lead Telluride (PbSnTe and PbTe)	Not covered		
7.8.21	Lead Tin Selenide ($Pb_{1-x}SN_xSe$)	Not covered		
7.8.22	Electrooptical Materials with the Chalcopyrite Structure	Not covered		
7.8.23	Rare Earth-Transition Metal Permanent Magnets (example: samarium cobalt and substituted samarium cobalt)	Not covered		
7.8.24	Gadolinium Gallium Garnet (GGG) and Substituted GGG as a Substrate for Magnetic Oxide Films	Not covered		
7.8.25	Materials for Magnetic Bubble Memories (Thin Magnetic Films Grown on Substrates)	Not covered		
7.8.26	Germanium - High Purity Detector Grade	Not covered		
7.8.27	3" or Greater Diameter Silicon Wafers	Not covered		
7.8.28	Detector Grade Silicon Wafer with Resistivity 10,000-15,000 ohm-cm	Not covered		
7.8.29	Indium Doped Extrinsic Silicon Crystal with Indium Concentration of about 10^{17} cm^{-3}	Not covered		

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
7.8.30	Silicon on Sapphire (SOS)	Not covered		
7.8.31	Pyrolytic Boron Nitride (PBN)	Not covered		
7.8.32	Not Used			
7.8.33	Gallium Antimonide	Not covered		
7.8.34	Indium Arsenide	Not covered		
7.8.35	Indium Antimonide	Not covered		
8.0	INSTRUMENTATION TECHNOLOGY			
8.1.1	Oscilloscope	6.1.1	6	3.1
8.1.2	Time Interval Analyzer	6.1.2	6	3.2
8.2.1	Radio Spectrum Analyzer	6.2.1	6	4.1
8.2.2	Panoramic and Digital Receiver	6.2.2	6	4.2
8.2.3	Real-Time Spectrum Analyzer	6.2.3	6	4.3
8.2.4	Frequency Counter	6.2.4	6	4.4
8.3.1	Frequency Standard	6.3.1	6	5.1
8.3.2	Frequency Synthesizer	6.3.2	6	5.2
8.3.3	Signal Generator	Not covered		
8.4.1	Network Analyzer	6.4.1	6	6.1
8.4.2	Not Used	-	-	-
8.4.3	Digital Voltage Measuring	6.4.3	6	6.4
8.4.4	Microwave Power Meter	Not covered		
8.4.5	Active Signal Acquisition Probe	6.4.2	6	6.3
8.5.1	Logic Analyzer	6.5.1	6	7.1
8.5.2	Microprocessor Development System	6.5.2	6	7.2
8.5.3	Analog-to-Digital and Digital-to-Analog Converter	6.5.3	6	7.3
8.5.4	Automatic Test Equipment	Not covered		
8.5.5	Digital Storage Oscilloscope and Digitizer	6.5.4	6	7.4

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
8.6.1	Recorder/Reproducer	6.6.1	6	8.1
		6.6.2	6	8.1
		6.6.3	6	8.1
		6.6.4	6	8.1
		6.6.5	6	8.1
		6.6.6	6	8.1
		6.6.7	6	8.1
		6.6.8	6	8.1
8.7.1	Photographic Interpretation	Not covered		
8.7.2	Laser Rangefinding	-	6	10.4
8.7.3	Laser Measurement	6.7.9	6	13.0
8.7.4	LIDAR/Laser Radar	6.7.8	6	10.4
8.7.5	Aerial and Streak Camera	Not covered		
8.7.6	High Speed Cinema Recording Camera	Not covered		
8.7.7	Microdensitometer	Not covered		
9.0	TELECOMMUNICATIONS TECHNOLOGY			
9.1.1	RF Communications System	3.5.1	3	7.6
9.1.2	Optical Communications System	6.7.5	6	10.1
9.1.3	Acoustic Communications System	Not covered		
9.1.4	Space Qualified Telecommunications	Not covered		
9.2.1	Circuit Switching	3.1	3	3.0
9.2.2	Message Switching	3.2	3	4.0
9.2.3	Packet Switching	3.3	3	5.0
9.3.1	Modem	3.5.1	3	7.6
9.3.2	Multiplexing	3.5.2	3	7.11
		3.5.3	3	7.12
10.0	COMMUNICATION, NAVIGATION, GUIDANCE, AND CONTROL TECHNOLOGY			
10.1.1.1	Spacecraft Stabilization	Not covered		
10.1.1.2	Spacecraft Altitude Control	Not covered		

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
10.1.1.3	Compensation Techniques for Space Environmental Effects	Not covered		
10.1.1.4	Satellite Thermal Design	Not covered		
10.1.1.5	Onboard Sensor Techniques Providing Control Information Critical Elements	Not covered		
10.1.3.1	Remote Control Techniques	Not covered		
10.1.4.1	Navigation and Positioning Techniques	Not covered		
10.1.4.2	Techniques for In-Water Speed Measurement and Integration	Not covered		
10.1.5	Submersible Guidance and Control	Not covered		
10.2.1	Inertial Navigation Systems Integration	4.1.1	4	3.1
10.2.2	Inertial Gimballed Platform	4.1.2	4	3.2
10.2.3	Inertial Strapdown Systems	4.1.3	4	3.3
10.2.4	Floated Ball-Bearing Gyroscope	4.1.4	4	3.4
10.2.5	Gas Bearing Gyroscope	4.1.5	4	3.4
10.2.6	Flexure Rotor Gyroscope	4.1.6	4	3.4
10.2.7	Ring Laser Gyroscope	4.1.7	4	3.4
10.2.8	Electrostatically Supported Gyroscope	4.1.8	4	3.4
10.2.9	Nuclear Magnetic Resonance Gyroscope	4.1.9	4	3.4
10.2.10	Fiber Optics Gyroscope	4.1.10	4	3.4
10.2.11	Low-Cost Gyroscope	4.1.11	4	3.4
		6.7.7	6	10.3
10.2.12	Accelerometer	4.1.12	4	3.5
10.2.13	Autopilot	4.1.13	4	3.7
10.2.14	Test, Calibration and Alignment	4.1.14	4	3.8

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
10.3.1.1	Radio Signal Conversion	4.2.7	4	4.3.2
10.3.1.2	Radio Signal Detection & Processing	4.2.8	4	4.3.3
10.3.1.3	Navigation Computation & Control	4.2.9	4	4.3.4
10.3.1.4	Not Used	-	-	-
10.3.1.5	Systems Integration	4.2.10	4	4.3.6
10.3.2.1	Radio Signal-to-Noise Enhancement	4.2.10	4	4.3.6
10.3.2.2	Antenna Matching Over a Multiplicity of User Allocated RF Band	4.2.1.1	4	4.4.2
10.3.2.3	Radio Signal Transmitting, Receiving, Detection and Processing	Not covered		
10.3.3.1	Utilization of Solid-State Digital Components in Systems Design	4.2.1	4	4.1
10.3.3.2	System Architecture	4.2.1	4	4.1
10.3.3.3	Ruggedized/Hardened Equipment	-	4	4.1
10.3.4.1	Improved HUD-Holographic Combiner	4.2.12	4	4.4.5
10.3.4.2	Voice Control Input	4.2.12	4	4.4.5
11.0	MICROWAVE TECHNOLOGY			
11.1.1	Electron Gun and Beam Design	5.20.1	5	20.5.1
11.1.2	Microwave Circuits	5.20.1	5	20.5.1
11.1.3	Microwave Tube Assembly	5.20.2	5	20.5.2
11.2	Microwave Solid State Device	5.23	5	23.0
11.3	High Power Microwave Control Component	5.23	5	23.0
11.4	Waveguide and Component	5.23	5	23.0
		5.22.1	5	22.5.1
		5.22.2	5	22.5.2

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
12.0	VEHICULAR TECHNOLOGY			
12.1.1	Laminar Flow Control (LFC)	2.1.1	2	3.6.1
12.1.2	Airfoil, Helicopter Rotor and Wing Designs	2.1.1 2.1.2	2 2	3.6.2 3.7
12.1.3	Computer-Aided Design and Manufacture (CAD/CAM)	2.1.1	2	3.6.3
12.1.4	Technologies For Integrating Sensor Subsystems	2.1.3	2	3.8.1
12.1.5	Control Configured Vehicles	2.1.3	2	3.8.2
12.1.6	Flight Control and Flight Management	2.1.3	2	3.8.3
12.1.7	Electromagnetic Hardening	2.1.3	2	3.8.4
12.1.8	High Contact Ratio, Double Helical (Herringbone) Gears	2.1.4	2	3.9.1
12.1.9	High Survivability (Loss of Lubrication)	-	2	3.9.2
12.1.10	Advanced Propellers	2.2.2	2	4.7.12
12.1.11	Advanced Structural Bonding	-	2	3.7.3
12.2.1	Hydrodynamic Design of Advanced Hull Forms	2.3.1	2	5.6.1
12.2.2	Foil and Foil Structure Design for Advanced Hydrofoils	2.3.1	2	5.6.2
12.2.3	Lightweight Marine Platform Structure	2.3.2	2	5.7.1
12.2.4	Flexible Curtains and Skirts for Air Bubble Supported Platforms	2.3.2	2	5.7.2
12.2.5	Automated Platform Controls for Hydrofoils and Other High Speed Marine Vehicles	2.3.3	2	5.8.1
12.2.6	Polymer Injection for Drag Reduction	2.3.4	2	5.9.5

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
12.3.1	Manned Submersibles, Untethered	4.4.1	4	6.2
12.3.2	Manned Submersibles, Tethered and Diving Equipment	4.4.1	4	6.2
12.3.3	Unmanned, Tethered and Towed Submersibles	4.4.2	4	6.4
12.3.4	Unmanned, Untethered Vehicles	4.4.3	4	6.5
12.3.5	Syntactic Foam	4.5	4	7.0
12.4.1	System Configuration, Aerodynamic and Thermodynamic Analysis	2.2.1	2	4.6.1
12.4.2	Variable Flowpath	2.2.1	2	4.6.2
12.4.3	Contrifugal Flow Compressor Aerodynamics	2.2.2	2	4.7.1
12.4.4	Axial Flow Fan and Compressor Aerodynamics	2.2.2	2	4.7.2
12.4.5	Turbine	2.2.2	2	4.7.3
12.4.6	Cooled Turbine	2.2.2	2	4.7.4
12.4.7	Rotating Propulsion System Structures	2.2.2	2	4.7.5
12.4.8	High DN Rolling Element Bearings	2.2.2	2	4.7.6
		1.5.1	1	8.2
12.4.9	Gas Film Bearing Design	2.2.2	2	4.7.7
12.4.10	Ceramic Hybrid Bearing Design	2.2.2	2	4.7.8
		1.5.2	1	8.3
12.4.11	Lube System Seals	2.2.2	2	4.7.9
12.4.12	Gaspath Sealing	2.2.2	2	4.7.10
12.4.13	Coating	2.2.2	2	4.7.11
		2.3.5	2	5.10.4
		1.2.3	1	4.6.2
12.4.14	Combustor Aerodynamics	2.2.3	2	4.8.1
12.4.15	Combustion System Structures	2.2.3	2	4.8.2
12.4.16	Afterburner/Ductburner Aerothermodynamics	2.2.3	2	4.8.3

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
12.4.17	Frames, Ducts, and Cases	2.2.3	2	4.8.4
12.4.18	Propulsion Systems Integration	2.2.4	2	4.9.1
12.4.19	Electronic Control & Diagnostics	2.2.4	2	4.9.2
12.4.20	Sensors, Activators, Interfaces and Interconnections for Advanced Engine Control Systems	2.2.4	2	4.9.3
12.4.21	Fuel Pumps	2.2.5	2	4.10.1
12.4.22	Electrical Power Generation	2.2.5	2	4.10.2
12.4.23	Inlet	2.2.6	2	4.11.1
12.4.24	Nozzles, Thrust Vectoring and Thrust Reversing	2.2.6	2	4.11.2
12.4.25	Wind Tunnel & Propulsion Test Cell	2.2.6	2	4.12.3
12.5.1	Gas Turbine Engine Moisture and Particulate Separator Systems	2.3.5	2	5.10.1
12.5.2	Protective Coating for Marine Gas Turbine Engines	2.3.5	2	5.10.2
12.5.3	Heavy Fuel Capability for Marine Gas Turbine Engines	2.3.5	2	5.10.3
12.5.4	High-Temperature Heat Exchanger	2.3.5	2	5.10.4
12.5.5	Lightweight Combined Gas and Steam Turbine (COGAS)	2.3.5	2	5.10.6
12.6.1	Composite Shafting	2.3.6	2	5.11.1
12.6.2	Lightweight Gearing	2.3.6	2	5.11.2
12.6.3	Water Cooled and Superconducting Electrical Machinery	2.3.6	2	5.11.3
12.6.4	Ship Propellers	2.3.7	2	5.12.1
12.6.5	Advanced Lift Fans	2.3.7	2	5.12.2
12.6.6	Large Advanced Waterjets	2.3.7	2	5.12.3
12.7.1	Photo Voltaic Cells	5.14.3	5	14.3

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
12.7.2	Radiactive Thermoelectric and Thermionic Generators	5.14.1	5	14.1
12.7.3	Fuel Cells	5.14.1	5	14.2
12.7.4	Aerospace Quality Nickel-Cadmium and Nickel Hydrogen Batteries			
12.7.5	Special Purpose Primary and Reserve Batteries	5.14.2	5	14.2
12.7.6	Lithium Primary and Secondary Batteries	5.14.2	5	14.2
12.7.7	High Energy Density - High-Temperature Secondary Batteries	5.14.2	5	14.2
12.7.8	Power Conditioning	Not covered		
12.7.9	Advanced Flywheels for Energy Storage	Not covered		
13.0	OPTICAL AND LASER TECHNOLOGY			
13.1.1	Fiber	6.9.1	6	12.6
13.1.2	Fiber Optic Cable	6.9.2	6	12.7
13.1.3	Source and Detector	6.9.4	6	12.10
13.1.4	Fiber Optic Connecting and Splicing	6.9.3	6	12.9
13.1.5	Optical Coupler	6.9.4	6	12.10
13.2	Integrated Optic	5.1	5	3.1
13.3	Filter	6.7.8	6	10.4
13.4	Mirror and Surface	Not covered		
13.5	Dye Laser	6.7.2	6	9.1
13.6	Gas Laser	6.7.3	6	9.2
13.7	Semiconductor Laser	6.7.4	6	9.3
13.8	Solid State Laser	6.7.1	6	9.4
13.9	Chemical Laser	6.8.2	6	11.3

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
14.0	SENSOR TECHNOLOGY			
14.1	Infrared, Optical and UV Sensor	4.8	4	11.0
14.2	Passive X-Ray Sensor		Not covered	
14.3	Conventional Acoustic Sensor		Not covered	
14.4	Fiber Optic Sensor System (FOSS)		Not covered	
14.5	Magnetometer and Magnetic Sensor		Not covered	
14.6	Gravity Meter		Not covered	
14.7.1	Systems Architecture Design and Integration	4.2.1	4	4.2.1
14.7.2	Transmitter	4.2.2	4	4.2.2
14.7.3	Advance Radar Antenna Design	4.2.3	4	4.2.3
14.7.4	Radar Receiver	4.2.4	4	4.2.4
14.7.5	Signal Processing	4.2.5	4	4.2.5
14.7.6	Display	4.2.6	4	4.2.6
14.7.7	Radar Absorbing Material	-	4	-
15.0	UNDERSEA SYSTEMS TECHNOLOGY			
15.1.1	Acoustic Propagation, Modeling and Forecasting	4.3.1	4	5.2
15.1.2	Acoustic Reception	4.3.2	4	5.3
15.1.3	Acoustic Transmission	4.3.3	4	5.4
15.2	Platform Acoustic		Not covered	
15.3	Heavy Lift Salvage		Not covered	
15.4	Not Used			
15.5	Deep Sea Sensor Implantation		Not covered	
15.6	Not Used			
15.7	Research Facility	4.3.2	4	5.4

MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	TWG NUMBER	SECTION NUMBER
16.0	CHEMICAL TECHNOLOGY			
16.1	Polymeric Material	1.3.4	1	5.5
16.2	Hydraulic Fluid	1.3.1	1	5.2
16.3	Synthetic Lubricating Oil and Base	1.3.2	1	5.3
16.4	Synthetic Elastomer	1.3.3	1	5.4
16.5	Atmospheric Purification	Not covered		

APPENDIX C

CROSS-REFERENCE LIST:

CCL NUMBER TO THE MCTL AND IDA TWG REPORTS

APPENDIX C

CROSS-REFERENCE LIST:

CCL NUMBER TO THE MCTL AND IDA TWG REPORTS

This list contains a cross-reference between the CCL items listed in the October 1980 Export Administration Regulations, the October 1980 DoD Militarily Critical Technologies List, the IDA TWG Reports, and the IDA Recommended Critical Technology (labeled IDA CT) Numbers.

Column 1 lists the CCL number and column 2 the MCTL number. Column 3 identifies the MCTL title or indicates why no MCTL has been identified.

Column 4 lists the IDA CT number and column 5 the section of the IDA report describing that CT. The first digit of the IDA CT number indicates the TWG responsible for the CT concerned and in whose report it is described.

A dash in the MCTL number column indicates that no MCTL has been identified for that corresponding CCL number. A dash in the IDA CT number column indicates that IDA did not identify a critical technology for the particular CCL or MCTL listed in columns 1 and 2. A dash in column 5 indicates that the particular CCL or MCTL was not discussed by IDA in the TWG reports.

CROSS-REFERENCE LIST
CCL NUMBER TO MCTL

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1072	-	Now covered in 1312	-	-
1075	5.3.8	Spin- and Flow-Forming Machines	1.1.2	3.4
1080	-	No MCTL Identified	-	3.10
				4.12
1081	-	No MCTL Identified	-	3.10
1086	-	No MCTL Identified	-	4.12
1088	-	No MCTL Identified	-	3.10
1091	5.3.6	Numerically Controlled Machine Tools	1.1.3	3.5
1093	5.3.6		1.1.3	3.5
			6.7.9	13.0
1110	-	No MCTL Identified	-	3.10
1118	-	No MCTL Identified	-	3.11.1
1129	5.3.9	High Vacuum	-	3.11.2
1131	-	No MCTL Identified	-	3.11.3
1133	-	No MCTL Identified	-	3.11.4
1142	16.1	Polymeric Material	1.3.4	5.5
1145	-	No MCTL Identified	-	3.11.5
1203	-	No MCTL Identified	-	3.8.2
1205	12.7.1	Photo Voltaic Cells	5.14.3	14.3
	12.7.2	Radioactive Thermoelectric and Thermionic Generators	5.14.1	14.1
	12.7.3	Fuel Cells	5.14.1	14.1
	12.7.4	Aerospace Quality Nickel-Cadmium and Nickel Hydrogen Batteries	-	-
	12.7.5	Special Purpose Primary and Reserve Batteries	5.14.2	14.2
	12.7.6	Lithium Primary and Secondary Batteries	5.14.2	14.2

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1205 (Cont'd)	12.7.7	High Energy Density - High-Temperature Secondary Batteries	5.14.2	14.2
	12.7.8	Power Conditioning	-	-
	12.7.9	Advanced Flywheels for Energy Storage	-	-
1206	6.2.1	High Current Particle Beam Generation	6.8.1	11.2
	6.2.1.1	Post Injection (Particle Beam Accelerator)	6.8.1	11.2 11.2
	6.2.2	Short Term Energy Generating Subsystem	6.8.1	11.2
	6.2.3	Beam Propagation	-	-
	6.2.4	Beam-Target Coupling	-	-
	6.2.5	Beam Control Subsystem	-	-
	6.2.6	Beam Neutralization	-	-
1305	5.3.3	Isothermal Rolling Mill	1.1.5	3.7
	5.3.4	Isothermal Metal Working Technology	-	-
1312(a)	5.3.2	High-Temperature Press	1.1.1	3.2, 3.3, 3.12
(b)	-	Hydraulic Press (Not covered)	-	-
(c)	5.3.1	Hot Isostatic Pressing (HIP)	1.2.11	4.12
1352	-	No MCTL Identified	-	3.9
1353	-	Not Covered	-	-
1355	-	Not Covered	-	-
1356	-	Not Tasked	-	-
1357	5.2.2	Filament Winding, Tape Laying and Interlacing	-	3.10
1358	-	Not Covered	-	-
1361	-	No MCTL Identified	-	3.10, 4.12
1362	-	No MCTL Identified	-	3.10
1370	5.3.7	Precision Turning Machines	1.1.4	3.6
1371	12.4.8	High DN Roller Element Bearings	1.5.1	8.2
	5.2.5	Ceramics	1.5.2	8.3
1416	12.2.1	Hydrodynamic Design of Advanced Hull Forms	2.3.1	5.6

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1416 (Cont'd)	12.2.2	Foil and Foil Structure Design for Advanced Hydrofoils	2.3.1	5.6
	12.2.3	Lightweight Marine Platform Structure	2.3.2	5.7
	12.2.4	Flexible Curtains and Skirts for Air Bubble Supported Platforms	2.3.2	5.7
	12.2.5	Automated Platform Controls for Hydrofoils and Other High Speed Marine Vehicles	2.3.3	5.8
	12.2.6	Polymer Injection for Drag Reduction	2.3.4	5.9
	12.5.1	Gas Turbine Engine Moisture and Particulate Separator Systems	2.3.5	5.10
	12.5.2	Protective Coating for Marine Gas Turbine Engines	2.3.5 1.2.8	5.10
	12.5.3	Heavy Fuel Capability for Marine Gas Turbine Engines	2.3.5	5.10
	12.5.4	High-Temperature Heat Exchanger	2.3.5	5.10
	12.5.5	Lightweight Combined Gas and Steam Turbine (COGAS)	2.3.5	5.10
	12.6.1	Composite Shafting	2.3.6	5.11
	12.6.2	Lightweight Gearing	2.3.6	5.11
	12.6.3	Water Cooled and Superconducting Electrical Machinery	2.3.6	5.11
	12.6.4	Ship Propellers	2.3.7	5.12
	12.6.5	Advanced Lift Fans	2.3.7	5.12
	12.6.6	Large Advanced Waterjets	2.3.7	5.12
1418	12.3.1	Manned Submersibles Untethered	4.4.1	6.2
	12.3.2	Manned Submersibles, Tethered and Diving Equipment	4.4.1	6.2
	12.3.3	Unmanned, Tethered and Towed Submersibles	4.4.2	6.4
	12.3.4	Unmanned, Untethered Vehicles	4.4.3	6.5

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1431	12.4.6	Cooled Turbine	2.2.2	4.7
	12.4.7	Rotating Propulsion System Structures	2.2.2	4.7
	12.4.8	High DN Rolling Element Bearings	2.2.2	4.7
	12.4.9	Gas Film Bearing Design	2.2.2	4.7
	12.4.10	Ceramic Hybrid Bearing Design	2.2.2	4.7
	12.4.11	Lube System Seals	2.2.2	4.7
	12.4.12	Gaspath Sealing	2.2.2	4.7
	12.4.13	Coating	2.2.2	4.7
	12.4.14	Combustor Aerodynamics	2.2.3	4.8
	12.4.15	Combustion System Structures	2.2.3	4.8
	12.4.16	Afterburner/Ductburner Aerothermo-dynamics	2.2.3	4.8
	12.4.17	Frames, Ducts, and Cases	2.2.3	4.8
	12.4.18	Propulsion Systems Integration	2.2.4	4.9
	12.4.19	Electronic Control and Diagnostics	2.2.4	4.9
	12.4.20	Sensors, Activators, Interfaces and Interconnections for Advanced Engine Control Systems	2.2.4	4.9
	12.4.21	Fuel Pumps	2.2.5	4.10
	12.4.22	Electrical Power Generation	2.2.5	4.10
	12.4.23	Inlet	2.2.6	4.11
	12.4.24	Nozzles, Thrust Vectoring and Thrust Reversing	2.2.6	4.11
	12.4.25	Wind Tunnel and Propulsion Test Cell	2.2.6	4.11
	12.2.1	Hydrodynamic Design of Advanced Hull Forms	2.3.1	5.6
	12.2.2	Foil and Foil Structure Design for Advanced Hydrofoils	2.3.1	5.6
	12.2.3	Lightweight Marine Platform Structure	2.3.2	5.7
	12.2.4	Flexible Curtains and Skirts for Air Bubble Supported Platforms	2.3.2	5.7

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1431 (Cont'd)	12.2.5	Automated Platform Controls for Hydrofoils and Other High Speed Marine Vehicles	2.3.3	5.8
	12.2.6	Polymer Injection for Drag Reduction	2.3.4	5.9
	12.5.1	Gas Turbine Engine Moisture and Particulate Separator Systems	2.3.5	5.10
	12.5.2	Protective Coating for Marine Gas Turbine Engines	2.3.5	5.10
	12.5.3	Heavy Fuel Capability for Marine Gas Turbine Engines	2.3.5	5.10
	12.5.4	High-Temperature Heat Exchanger	2.3.5	5.10
	12.5.5	Lightweight Combined Gas and Steam Turbine (COGAS)	2.3.5	5.10
	12.6.1	Composite Shafting	2.3.6	5.11
	12.6.2	Lightweight Gearing	2.3.6	5.11
	12.6.3	Water Cooled and Superconducting Electrical Machinery	2.3.6	5.12
	12.6.4	Ship Propellers	2.3.7	5.12
	12.6.5	Advanced Lift Fans	2.3.7	5.12
	12.6.6	Large Advanced Waterjets	2.3.7	5.12
1460	12.1.1	Laminar Flow Control (LFC)	2.1.1	3.6
	12.1.2	Airfoil, Helicopter Rotor and Wing Designs	2.1.1 2.1.2	3.6 3.7
	12.1.3	Computer-Aided Design and Manufacture (CAD/CAM)	2.1.1	3.6
	12.1.4	Technologies for Integrating Sensor Subsystems	2.1.3	3.8
	12.1.5	Control Configured Vehicles	2.1.3	3.8
	12.1.6	Flight Control and Flight Management	2.1.3	3.8
	12.1.7	Electromagnetic Hardening	2.1.3	3.8

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1460 (Cont'd)	12.1.8	High Contact Ratio, Double Helical Herringbone) Gears	2.1.4	3.9
	12.1.9	High Survivability (Loss of Lubrication)	-	-
	12.1.10	Advanced Propellers	2.2.2	4.7
	12.1.11	Advanced Structural Bonding	-	-
	12.4.1	System Configuration, Aerodynamic and Thermodynamic Analysis	2.2.1	4.6
	12.4.2	Variable Flowpath	2.2.1	4.6
	12.4.3	Centrifugal Flow Compressor Aerodynamics	2.2.2	4.7
	12.4.4	Axial Flow Fan and Compressed Aerodynamics	2.2.2	4.7
	12.4.5	Turbine	2.2.2	4.7
	12.4.6	Cooled Turbine	2.2.2	4.7
	12.4.7	Rotating Propulsion System Structures	2.2.2	
	12.4.8	High DN Rolling Element Bearings	2.2.2	4.7
	12.4.9	Gas Film Bearing Design	2.2.2	4.7
	12.4.10	Ceramic Hybrid Bearing Design	2.2.2	4.7
	12.4.11	Lube System Seals	2.2.2	4.7
	12.4.12	Gaspath Sealing	2.2.2	4.7
	12.4.13	Coating	2.2.2	4.7
	12.4.14	Combustor Aerodynamics	2.2.3	4.8
	12.4.15	Combustion System Structures	2.2.3	4.8
	12.4.16	Afterburner/Ductburner Aero-thermodynamics	2.2.3	4.8
	12.4.17	Frames, Ducts, and Cases	2.2.3	4.8
	12.4.18	Propulsion Systems Integration	2.2.4	4.9
	12.4.19	Electronic Control and Diagnostics	2.2.4	4.9

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1460 (Cont'd)	12.4.20	Sensors, Activators, Interfaces and Interconnections for Advanced Engine Control Systems	2.2.4	4.9
	12.4.21	Fuel Pumps	2.2.5	4.10
	12.4.22	Electrical Power Generation	2.2.5	4.10
	12.4.23	Inlet	2.2.6	4.11
	12.4.24	Nozzles, Thrust Vectoring and Thrust Reversing	2.2.6	4.11
	12.4.25	Wind Tunnel and Propulsion Test Cell	2.2.6	4.11
1485	10.2.1	Inertial Navigation Systems Integration	4.1.1	3.1
	10.2.2	Inertial Gimballed Platform	4.1.2	3.2
	10.2.3	Inertial Strapdown Systems	4.1.3	3.3
	10.2.4	Floating Ball-Bearing Gyroscope	4.1.4	3.4
	10.2.5	Gas Bearing Gyroscope	4.1.5	3.4
	10.2.6	Flexure Rotor Gyroscope	4.1.6	3.4
	10.2.7	Ring Laser Gyroscope	4.1.7	3.4
			6.7.7	
	10.2.8	Electrostatically Supported Gyroscope	4.1.8	3.4
	10.2.9	Nuclear Magnetic Resonance Gyroscope	4.1.9	3.4
	10.2.10	Fiber Optics Gyroscope	4.1.10	3.4
			6.7.7	
	10.2.11	Low-Cost Gyroscope	4.1.11	3.4
	10.2.12	Accelerometer	4.1.12	3.5
	10.2.13	Autopilot	4.1.13	3.7
	10.2.14	Test, Calibration and Alignment	4.1.14	3.8
1501	10.3.1.1	Radio Signal Conversion	4.2.7	4.3.2
	10.3.1.2	Radio Signal Detection and Processing	4.2.8	4.3.3
	10.3.1.3	Navigation Computation and Control	4.2.9	4.3.4
	10.3.1.5	Systems Integration	-	-
	10.3.2.1	Radio Signal-to-Noise Enhancement	4.2.10	4.3.6

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1501 (Cont'd)	10.3.2.2	Antenna Matching Over a Multiplicity of User Allocated RF Band	4.2.11	4.4.2
	10.3.2.3	Radio Signal Transmitting, Receiving, Detection and Processing	4.2.11	4.4.2
	10.3.3.1	Utilization of Solid-State Components in System Design	4.2.1	4.1
	10.3.3.2	System Architecture	4.2.1	4.1
	10.3.3.3	Ruggedized/Hardened Equipment	-	-
	10.3.4.1	Improved HUD - Holographic Combiner	4.2.12	4.4.5
	10.3.4.2	Voice Control Input	4.2.12	4.4.5
	14.7.1	Systems Architecture, Design and Integration	4.2.1	4.1
	14.7.2	Transmitter	4.2.2	4.2.2
	14.7.3	Advanced Radar Antenna Design	4.2.3	4.2.3
	14.7.4	Radar Receiver	4.2.4	4.2.4
	14.7.5	Signal Processing	4.2.5	4.2.5
	14.7.6	Display	4.2.6	4.2.6
	14.7.7	Radar Absorbing Material	-	-
1502	-	No MCTL Identified	-	11.0
1505	-	Not Covered	-	-
1510	14.3	Conventional Acoustic Sensor	-	-
	15.1.1	Acoustic Propagation, Modeling and Forecasting	4.3.1	5.2
	15.1.2	Acoustic Reception	4.3.2	5.3
	15.1.3	Acoustic Transmission	4.3.3	5.4
	15.2	Platform Acoustic	-	-
	15.3	Heavy Lift Salvage	-	-
	15.5	Deep Sea Sensor Implantation	-	-
	15.7	Research Facility	4.3.2	5.3
1516	8.2.2	Panoramic and Digital Receiver	6.2.2	4.2
1517	-	Not Covered	-	-
1518	-	Not Covered	-	-

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1519	9.1.1	RF Communications System	3.5.1	7.6-7.9
	9.1.2	Optical Communications System	6.7.5	10.1
	9.3.1	Modem	3.5.1	7.6-7.9
	9.3.2	Multiplexing	3.5.2	7.11
			3.5.3	7.12
	13.1.4	Fiber Optic Connecting and Splicing	6.9.3	12.9
	13.1.5	Optic Coupler	6.9.4	12.10
1520	-	Not Covered	-	-
1521	-	No MCTL Identified	-	-
1522	6.1.1	High Energy Laser	6.8.2	11.1
	6.1.2	Mirror and Optical Device	6.8.2	11.1
	6.1.3	Beam Pointing and Control	-	-
	6.1.4	Mounting Subsystem	-	-
	6.1.5	Beam-Targeting Coupling	-	-
	6.1.6	Beam Propagation	-	-
	8.7.3	Laser Measurement	6.7.9	13.8
	8.7.4	LIDAR/LASER Radar	6.7.8	10.4
	8.7.2	Laser Rangefinding	-	-
	9.1.2	Optical Communications System	6.7.5	10.1
	10.2.7	Ring Laser Gyroscope	6.7.7	10.3
	10.2.10	Fiber Optics Gyroscope	6.7.7	10.3
	10.2.11	Low-Cost Gyroscope	6.7.7	10.3
	13.5	Dye Laser	6.7.2	9.1
	13.6	Gas Laser	6.7.3	9.2
	13.7	Semiconductor Laser	6.7.4	9.3
	13.8	Solid-State Laser	6.7.1	9.4
	13.9	Chemical Laser	6.8.2	11.1
	13.3	Filter	6.7.8	10.4
	13.4	Mirror and Surface	-	-

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1526	9.1.2	Optical Communications System	6.7.5	10.1
	13.1.1	Fiber	6.9.1	12.6
	13.1.2	Fiber Optic Cable	6.9.2	12.7
	13.1.3	Source and Detector	6.9.4	12.10
	13.1.4	Fiber Optic Connecting and Splicing	6.9.3	12.9
	13.1.5	Optic Coupler	6.9.4	12.10
1527	-	Not Tasked	-	-
1528	-	Now Covered by 1526	-	-
1529(a)	8.3.1	Frequency Standard	6.3.1	5.1
(b)(3)(i)	8.4.1	Network Analyzer	6.4.1	6.1
(b)(4)	6.2.3	Real-Time Spectrum Analyzer	6.2.3	4.3
(b)(6)(i)	8.5.1	Logic Analyzer	6.5.1	7.1
(b)(6)(ii)	8.5.2	Microprocessor Development System	6.5.2	7.2
(c)	8.2.4	Frequency Counter	6.2.4	4.4
(d)	8.1.2	Time Interval Analyzer	6.1.2	3.2
(f)	8.4.3	Digital Voltage Measuring	6.4.3	-
	8.4.4	Microwave Power Meter	-	-
(g)	8.5.5	Digital Storage Oscilloscope and Digitizer	6.5.4	7.4
1531	8.3.2	Frequency Synthesizer	6.3.2	5.2
	8.3.3	Signal Generator	-	-
1532	-	Not Tasked	-	-
1533	8.2.1	Radio Spectrum Analyzer	6.2.1	4.1
1534	8.7.1	Photographic Interpretation	-	-
	8.7.7	Microdensitometer	-	-
1537	11.2	Microwave Solid-State Device	5.23	23.0
	11.3	High Power Microwave Control Unit	5.23	23.0
	11.4	Waveguide and Component	5.23	23.0
	-	No MCTL Identified	5.22.1	22.5.1
	-	No MCTL Identified	5.22.2	22.5.2
1541	8.1.1	Oscilloscope	6.1.1	3.1
1542	-	No MCTL Identified	5.17	17.0

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1544	7.2.2	Diodes	5.5.1	5.5.1
			5.5.2	5.5.2
1545	7.2.1	Discrete Transistors	5.4.1	4.5
			5.4.2	4.6
1547	7.2.3	Thyristors	5.9.1	9.5
			5.9.2	9.5
1548	7.3.1	Semiconductor Devices	5.6.1	6.5.1
			5.6.2	6.5.2
1549	7.3.2	Photomultiplier Tubes	5.19	19.0
1553			5.21	21.0
1555	7.3.3	Image Intensifiers	5.18	18.0
1556	7.3.3	Image Intensifiers	5.18	18.0
1558	11.1.1	Electron Gun and Beam Design	5.20.1	20.5.1
	11.1.2	Microwave Circuits	-	-
	11.1.3	Microwave Tube Assembly	5.20.2	20.5.2
1559	-	No MCTL Identified	5.17	17.0
1560	7.6.2	Monolithic Ceramic Capacitors	5.10	10.0
1561			4.6	9.0
	14.1	Infrared, Optical and UV Sensor	4.8.1	11.0
1564(II)(a) (II)(c)	7.6.4	Printed Circuit Boards	5.15	15.0
	7.1.1	Wafer Preparation	5.1.2	3.1.7.1
	7.1.2	Epitaxy	5.1.3	3.1.7.2
	7.1.3	Oxidation	5.1.4	3.1.7.3
	7.1.4	Maskmaking	5.1.5	3.1.7.4
	7.1.5a	Lithography-Resisting Processing	5.1.6	3.1.7.5
	7.1.5b	Lithographic-Wafer Imaging	5.1.6	3.1.7.5
	7.1.6	Selective Removal	5.1.7	3.1.7.6
	7.1.7	Diffusion/Implantation	5.1.8	3.1.7.7
	7.1.8	Thin Film Deposition	5.1.9	3.1.7.8
	7.1.9	Assembly	5.1.10	3.1.7.9
	7.1.10	Testing	5.1.11	3.1.7.10
	7.1.11	Facilities	5.1.12	3.1.7.11

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1564	7.1.12	IC Design	5.1.1	3.1.6
(Cont'd)	7.1.13	Hybrid Microcircuits	5.2	3.2
	7.1.14	Microwave Microcircuits	5.3	3.3
	13.2	Integrated Optic	5.1	3.1
1565				
(a)(b)(f)	2.7	Analog and Hybrid Computer	7.11.1	13.8
	4.2	Analog and Hybrid Computing Technique	7.11.2	13.8
(c)(4)(5)	9.2.1	Circuit Switching	3.1	3.0
	9.2.2	Message Switching	3.2	4.0
	9.2.3	Packet Switching	3.3	5.0
(d)(e)	1.1	Network Architecture	7.1.4	3.8
	1.2	Implementation	7.1.5	3.8.3
	4.1	Automated Real-Time Control Utilization of Data Processing	7.1.2	3.6
	2.1.1	General System Architecture	7.1.1	3.5
	2.1.2	Processor Architecture	7.1.2	3.6
	2.1.3	Memory Hierarchy	7.1.3	3.7
	2.2.1	Computer Hardware Development	7.2.1	4.6
			7.2.2	4.7
	2.2.2	Computer Hardware Production	7.2.3	4.8
	2.2.3	Computerized Manufacturing Control System (CMCS)	7.2.3	4.8
		Computer-Assisted Manufacturing (CAM)	7.2.4	4.9
	2.2.4	Interconnections	7.2.5	4.11
	2.2.5	Production Testing	7.2.6	4.12
	2.2.6	Computer Cooling	7.2.7	4.13
	2.2.7	Power Supply and Distribution	7.2.8	4.14
	2.3.1	Computer-Assisted Servicing (CAS)	7.3.1	5.2
	2.3.2	Computer System Configuration Management	7.3.2	5.3
	2.3.3	Digital Computer Security	7.3.3	5.4

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1565(d)(e)	2.3.4	Computer-Assisted Training/ Simulation	7.3.4	5.5
(Cont'd)	2.4.1	Semiconductor Logic and Memory Assembly	7.5.1	7.6
	2.4.2	Magnetic Core Memory	7.5.2	7.7
	2.4.3	Josephson Junction	7.5.3	7.8
	2.4.4	Charge-Coupled Device (CCD) Memory	7.5.4	7.9
	2.4.5	Magnetic Bubble Logic and Memory	7.5.5	7.10
	2.4.6	Magnetic Cross-Tie Memory	7.5.6	7.11
	2.4.7	Plated Wire Memory	7.5.7	7.12
	2.4.8	Microprocessor	7.5.8	7.13
	3.1.1	Software Life-Cycle Management	7.4.1	6.7
	3.1.2	Software Library Data Base	7.4.2	6.8
	3.1.3	Software Development Tools	7.4.1	6.7
	3.1.4	Formal Methods and Tools for Developing Trusted Software	7.4.2	6.8
	3.2.1	Maintenance of Large Software Product	7.4.1	6.7
	3.3.1	Secure Software	7.4.2	6.8
	3.3.2	Large Self-Adapting Software System	7.4.2	6.8
	4.4	Automated Real-Time Control Related Software	7.4.1	6.7
	2.8.1	Speech Processing	7.13.1	15.2
	2.8.2	Artificial Intelligence	7.13.2	15.3
1565(g)(h)	2.5.1.1	Magnetic Disc Read/Write Head	7.6.1	8.8
	2.5.1.2	Magnetic Disc Recording Media	7.6.2	8.9
	2.5.1.3	Winchester Disc	7.6.3	8.10
	2.5.1.4	Flexible Disc Drive	7.6.4	8.11
	2.5.2.1	Conventional Magnetic Tape Drive	7.7.1	9.6
	2.5.2.2	Cartridge/Cassette	7.7.2	9.7
	2.5.3.1	Electron Beam Memory	7.8.1	10.6
	2.5.3.2	Optical Cryogenic Memory	7.8.2	10.7

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1565	2.5.3.3	Holographic/Laser Memory	7.8.3	10.8
(Cont'd)	2.5.3.4	Video Disc Digital Recording	7.8.4	10.9
	2.5.3.5	Archival Magnetic Tape Memory	7.7.2	9.7
	4.3	Automated Real-Time Control Display	-	-
	2.6.1	Alphanumeric and Graphic Terminal	7.9.1	11.2
			7.9.2	11.3
			7.9.3	11.4
			7.9.4	11.5
	2.6.2.1	Digital Flat-Bed	7.10.1	12.2
	2.6.2.2	Non-Impact Line Printer	7.10.2	12.3
1568	8.5.3	Analog-to-Digital and Digital-to-Analog Converter	6.5.3	7.3
1570	7.3.4	Thermoelectric Coolers	5.16	16.0
1571	14.5	Magnetometer and Magnetic Sensor	-	-
1572	8.6.1	Recorder/Reproducer	6.6.1	8.1
			6.6.2	8.1
			6.6.3	8.1
			6.6.4	8.1
			6.6.5	8.1
			6.6.6	8.2
			6.6.7	8.4
			6.6.8	8.4
			7.6.1	8.8
			7.6.2	8.9
			7.6.3	8.10
			7.6.4	8.11
			7.7.1	9.6
			7.7.2	9.7
			7.8.1	10.6
			7.8.2	10.7
			[illegible]	10.8
			[illegible]	[illegible]

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1584	8.4.1	Network Analyzer	6.4.1	6.2
	8.4.5	Active Signal Acquisition Probe	6.4.2	6.3
(f)	8.5.4	Digital Storage Oscilloscope and Digitizer	6.5.4	7.4
1585	8.7.5	Aerial and Streak Camera	-	-
	8.7.6	High Speed Cinema Recording Camera	-	-
1586	7.4	Acoustic Wave Device	5.7	7.0
1587	7.6.3	Quartz Crystals	5.12	12.0
1588			7.6.1	8.8
			7.6.2	8.9
			7.6.3	8.10
			7.6.4	8.11
	7.5.1	Magnetic Bubble Memories	5.8.1	8.1
	7.5.2	Plated Wire Memories	5.8.2	8.2
	7.5.3	Cross-Tie Memories	5.8.3	8.3
(f)	7.6.1	Ferrite Materials	5.11	11.0
1595	14.6	Gravity Meter	-	-
1631	5.1.1	Magnetic and Amorphous Metals	1.2.1	4.2
1635	-	No MCTL Identified	-	4.3
1648	-	(Cobalt)	1.2.9	4.10
1649	5.1.5	Niobium (Columbian) Alloys	1.2.4	4.7.1
1658	5.1.6	Molybdenum Alloys	1.2.5	4.7.2
1661	5.1.2	(Nickel)	1.2.9	4.10
1670	-	Not Covered	-	-
1671	5.1.3	Titanium Alloys	1.2.2	4.6.1
1673	-	No MCTL Identified	-	6.2
1701	-	No MCTL Identified	-	5.6
1702	-	Hydraulic Fluid	1.3.1	5.2
1715	-	No MCTL Identified	-	6.3
1746	-	Polymeric Material	1.3.4	5.5

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
1754	16.1	Polymeric Foam	1.3.4	5.5
	16.2	Hydraulic Fluid	1.3.1	5.2
	16.3	Synthetic Lubricating Oil and Grease	1.3.2	5.3
1755	16.2	Hydraulic Fluid	1.3.1	5.2
	16.3	Synthetic Lubricating Oil and Base	1.3.2	5.3
1757	7.8.2	Bulk Gallium Arsenide (GaAs)	-	-
	7.8.17	Mercury Cadmium Telluride (Bulk and Thin Films)	-	-
1759	12.3.5	Syntactic Foam	4.5	7.0
1760	7.8.14	Niobates and Tantalates(e.g., $LiNbO_3$, $LiTaO_3$)	-	-
1763	5.2.1	Fibers and Filamentary Materials	1.4.1	7.2
	5.2.3	Advanced Organic Matrix Composites	1.4.2	7.3
	5.2.4	Metal and Graphite Matrix Composites	-	7.3
	5.2.6	Superalloy Composites	-	7.5
1767			6.9.1	12.6
1781	16.3	Synthetic Lubricating Oil and Grease	1.3.2	5.3
1801	16.4	Synthetic Elastomer	1.3.3	5.4
2018				
2120	7.7.1	Superconducting Digital Components	5.13	13.0
	7.7.2	Superconducting RF Components	-	-
	7.7.3	Cryogenic Coolers	-	13.0
	5.1.13	Superconducting Materials	-	-
2317	-	Not Covered	-	-
2319	-	No MCTL Identified	-	3.11
2404	-	Not Tasked	-	-
2406	-	Not Tasked	-	-
2409	-	Not Tasked	-	-
2410	-	Not Tasked	-	-
2603	-	Not Covered	-	-
2616	-	Not Covered	-	-

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
2708	-	Not Covered	-	-
3131	-	Not Tasked	-	-
3261	-	Not Tasked	-	-
3336	-	Not Covered	-	-
3362	-	Not Tasked	-	-
3363	-	Not Tasked	-	-
3604	-	Not Tasked	-	-
3605	-	Not Tasked	-	-
3607	-	Not Tasked	-	-
3608	-	Not Covered	-	-
3609	-	Not Tasked	-	-
3709	-	Not Tasked	-	-
3711	-	Not Tasked	-	-
4203	5.3.5	High-Temperature Furnace and Coating Unit	1.1.6	3.8
4261	-	No MCTL Identified	6.8.1	11.2
4355	-	Not Tasked	-	-
4409	12.2.1	Hydrodynamic Design of Advanced Hull Forms	2.3.1	5.6
	12.2.2	Foil and Foil Structure Design for Advanced Hydrofoils	2.3.1	5.6
	12.2.3	Lightweight Marine Platform Structure	2.3.2	5.7
	12.2.4	Flexible Curtains and Skirts for Air Bubbles Supported Platforms	2.3.2	5.7
	12.2.5	Automated Platform Controls for Hydrofoils and Other High Speed Marine Vehicles	2.3.3	5.8
	12.2.6	Polymer Injection for Drag Reduction	2.3.4	5.9
	12.5.1	Gas Turbine Engine Moisture and Particulate Separator Systems	2.3.5	5.10
	12.5.2	Protective Coating for Marine Gas Turbine Engines	2.3.5	5.10

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
4409 (Cont'd)	12.5.3	Heavy Fuel Capability for Marine Gas Turbine Engines	2.3.5	5.10
	12.5.4	High-Temperature Heat Exchanger	2.3.5	5.10
	12.5.5	Lightweight Combined Gas and Steam Turbine (COGAS)	2.3.5	5.10
	12.6.1	Composite Shafting	2.3.6	5.11
	12.6.2	Lightweight Gearing	2.3.6	5.11
	12.6.3	Water Cooled and Superconducting Electrical Machinery	2.3.6	5.11
	12.6.4	Ship Propellers	2.3.7	5.12
	12.6.5	Advanced Lift Fans	2.3.7	5.12
	12.6.6	Large Advanced Waterjets	2.3.7	5.12
4431	12.2.1	Hydrodynamic Design of Advanced Hull Forms	2.3.1	5.6
	12.2.2	Foil and Foil Structure Design for Advanced Hydrofoils	2.3.1	5.6
	12.2.3	Lightweight Marine Platform Structure	2.3.2	5.7
	12.2.4	Flexible Curtains and Skirts for Air Bubble Supported Platforms	2.3.2	5.7
	12.2.5	Automated Platform Controls for Hydrofoils and Other High Speed Marine Vehicles	2.3.3	5.8
	12.2.6	Polymer Injection for Drag Reduction	2.3.4	5.9
	12.5.1	Gas Turbine Engine Moisture and Particulate Separator Systems	2.3.5	5.10
	12.5.2	Protective Coating for Marine Gas Turbine Engines	2.3.5	5.10
	12.5.3	Heavy Fuel Capability for Marine Gas Turbine Engines	2.3.5	5.10
	12.5.4	High-Temperature Heat Exchanger	2.3.5	5.10
	12.5.5	Lightweight Combined Gas and Steam Turbine (COGAS)	2.3.5	5.10
	12.6.1	Composite Shafting	2.3.6	5.11

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
4431	12.6.2	Lightweight Gearing	2.3.6	5.11
(Cont'd)	12.6.3	Water Cooled and Superconducting Electrical Machinery	2.3.6	5.11
	12.6.4	Ship Propellers	2.3.7	5.12
	12.6.5	Advanced Lift Fans	2.3.7	5.12
	12.6.6	Large Advanced Waterjets	2.3.7	5.12
4460	-	No MCTL Identified	2.1.1	3.6.1
			2.1.2	3.6.2
			2.1.3	3.8.1
			2.1.4	3.9.1
4516	-	Not Covered	-	-
4519	14.4	Fiber Optic Sensor System (FOSS)	-	-
4522	8.7.3	Laser Measurement	6.7.9	13.0
4529	-	Not Covered	-	-
4584	-	Now Covered by 1541 and 1584	-	-
4585	8.7.5	Aerial and Streak Camera	-	-
	8.7.6	High Speed Cinema Recording Camera	-	-
4589		Now covered by 1534	-	-
4590	-	No MCTL Identified	-	-
4592	-	Not Covered	-	-
4601	-	Not Covered	-	-
4635	5.1.14	Pressure Pipe and Fittings	1.2.18	4.19
4707	-	Not Covered	-	-
4721	-	Not Covered	-	-
4746	16.1	Polymeric Material	1.3.4	5.5
4754	16.1	Polymeric Material	1.3.4	5.5
4755(a)	16.2	Hydraulic Fluid	1.3.1	5.2
(b)	16.1	Polymeric Material	1.3.4	5.5
4757	-	Not Covered	-	-
4994	-	Not Tasked	-	-
4997	-	Not Tasked	-	-

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
4998	-	Not Tasked	-	-
5399	-	Not Tasked	-	-
5406	-	Not Tasked	-	-
5431	-	Not Covered	-	-
5510	-	Not Covered	-	-
5565	-	Not Covered	-	-
5568	-	Not Covered	-	-
5585	-	Not Covered	-	-
5595	14.6	Gravity Meter	-	-
5596	-	Not Covered	-	-
5799	-	Not Covered	-	-
New	5.1.4	High-Temperature Coatings for Superalloys and Titanium	1.2.3 1.2.8	4.6.2 4.9
New	5.1.7	Tungsten Alloys	1.2.6	4.7.3
New	5.1.8	Casting and Coating of Intricate Hollow Superalloy Shapes	1.2.8	4.9
New	5.1.9	Plasma Spraying	1.2.17	4.18
New	5.1.10	Advanced Powder Metallurgy	1.2.9	4.5, 4.10
New	5.1.11	Superplastic Forming/Diffusion Bonding (SPF/DB)	1.2.10	4.11
New	5.1.12	Titanium, Nickel and Iron Aluminides	1.2.16	4.17
New	5.3.4	Isothermal Metal Working	1.2.15	4.16
New	5.3.11	Laser Processing Technology	1.2.14	4.15
New	5.3.12	High Performance Welding	1.2.13	4.14
New	5.3.13	Fracture Analysis, Nondestructive Evaluation (NDE) and Control	1.2.12	4.13
New	5.3.14	Test Equipment for Integrated Structural Testing	-	-
New	6.3	Microwave Energy Transmission	-	-

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
New	7.8.1	Bulk Indium Phosphide (InP)	-	-
New	7.8.3	Vapor Phase Epitaxy of In_{1-x} $Ga_xP_{1-y}ASy$ on InP	-	-
New	7.8.4	Lead Lanthanum Zirconium Titanate (PZLT)	-	-
New	7.8.5	Lead Zirconium Titanate (Pb (ZrTi) O_3 PZT)	-	-
New	7.8.6	MgO (Magnesium Oxide, Periclase)	-	-
New	7.8.7	Thin Film Interference Coatings for Optics and Other Applications by Vacuum Deposition		
New	7.8.8	Sodium and Potassium Halides (NaF, NaCℓ, KCℓ, KBr, etc.)	-	-
New	7.8.9	Thallium Bromoidiode ($ThBr_xI_{1-x}$, KRS-5)	-	-
New	7.8.10	Dehydrogen Phosphates (ADP, KDP, KD*P, CD*P, CD*A, etc.)	-	-
New	7.8.11	Bismuth Silicon Oxide (BSO, $Bi_{12}SiO_{20}$) Bismuth Germanium Oxide (BGO, $Bi_{12}GeO_{20}$)	-	-
New	7.8.12	Polyvalent Binary Fluorides (e.g., BaF_2, CeF_3, LaF_4, ThF_4, ZrF_4)	-	-
New	7.8.13	Yttrofluorides (e.g., $LiYF_4$, KY_3F_{10}, etc.)	-	-
New	7.8.15	Neodymium Laser Hosts (especially YAG ($Y_3Aℓ_5O_{12}$), but also including $La_2Be_2O_5$, NdP_5O_{14}, $K_5NdLi_5F_{10}$, etc.)	-	-
New	7.8.16	Lanthanum Chloride Laser Materials ($LaCl_3:Pr^{3+}$, $:Er^{3+}$, etc.)	-	-
New	7.8.18	Cadmium Telluride Crystals	-	-
New	7.8.19	Lead Telluride (PbTe)	-	-

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
New	7.8.20	Epitaxial Lead Tin Telluride and Lead Telluride (PbSnTe and PbTe)	-	-
New	7.8.21	Lead Tin Selenide ($Pb_{1-x}SN_xSe$)	-	-
New	7.8.22	Electrooptical Materials with the Chalcopyrite Structure	-	-
New	7.8.23	Rare Earth-Transition Metal Permanent Magnets (example: samarium cobalt and substituted samarium cobalt)	-	-
New	7.8.24	Gadolinium Gallium Garnet (GGG) and Substituted GGG as a Substrate for Magnetic Oxide Films	-	-
New	7.8.25	Materials for Magnetic Bubble Memories (Thin Magnetic Films Grown on Substrates)	-	-
New	7.8.26	Germanium - High Purity Detector Grade	-	-
New	7.8.27	3" or Greater Diameter Silicon Wafers	-	-
New	7.8.28	Detector Grade Silicon Wafer with Resistivity 10,000-15,000 ohm-cm	-	-
New	7.8.29	Indium Doped Extrinsic Silicon Crystal with Indium Concentration of about 10^{17} cm^{-3}	-	-
New	7.8.30	Silicon on Sapphire (SOS)	-	-
New	7.8.31	Pyrolytic Boron Nitride (PBN)	-	-
New	7.8.32	Not Used	-	-
New	7.8.33	Gallium Antimonide	-	-
New	7.8.34	Indium Arsenide	-	-
New	7.8.35	Indium Antimonide	-	-
New	10.1.1.1	Spacecraft Stabilization	-	-
New	10.1.1.2	Spacecraft Altitude Control	-	-

CCL NUMBER	MCTL NUMBER	MCTL ITEM	IDA CT NUMBER	SECTION NUMBER
New	10.1.1.3	Compensation Techniques for Space Environmental Effects	-	-
New	10.1.1.4	Satellite Thermal Design	-	-
New	10.1.1.5	Onboard Sensor Techniques Providing Control Information Critical Elements	-	
New	10.1.3.1	Remote Control Techniques	-	-
New	10.1.4.1	Navigation and Positioning Techniques	-	-
New	10.1.4.2	Techniques for Water Speed Measurement and Integration	-	-
New	10.1.5	Submersible Guidance and Control	-	-
New	14.2	Passive X-ray Sensor	-	-
New	16.5	Atmospheric Purification	-	-

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