DUAL-USE LIST - CATEGORY 2 - MATERIALS PROCESSING

TABLE - DEPOSITION TECHNIQUES - NOTES

1. The term 'coating process' includes coating repair and refurbishing as well as original coating.

2. The term 'alloyed aluminide coating' includes single or multiple-step coatings in which an element or elements are deposited prior to or during application of the aluminide coating, even if these elements are deposited by another coating process. It does not, however, include the multiple use of single-step pack cementation processes to achieve alloyed aluminides.

3. The term 'noble metal modified aluminide' coating includes multiple-step coatings in which the noble metal or noble metals are laid down by some other coating process prior to application of the aluminide coating.

4. The term 'mixtures thereof' includes infiltrated material, graded compositions, co-deposits and multilayer deposits and are obtained by one or more of the coating processes specified in the Table.

5. 'MCrAlX' refers to a coating alloy where M equals cobalt, iron, nickel or combinations thereof and X equals hafnium, yttrium, silicon, tantalum in any amount or other intentional additions over 0.01 weight percent in various proportions and combinations, except:
   a. CoCrAlY coatings which contain less than 22 weight percent of chromium, less than 7 weight percent of aluminium and less than 2 weight percent of yttrium;
   b. CoCrAlY coatings which contain 22 to 24 weight percent of chromium, 10 to 12 weight percent of aluminium and 0.5 to 0.7 weight percent of yttrium; or
   c. NiCrAlY coatings which contain 21 to 23 weight percent of chromium, 10 to 12 weight percent of aluminium and 0.9 to1.1 weight percent of yttrium.

6. The term 'aluminium alloys' refers to alloys having an ultimate tensile strength of 190 MPa or more measured at 293 K (20°C).

7. The term 'corrosion resistant steel' refers to AISI (American Iron and Steel Institute) 300 series or equivalent national standard steels.

8. 'Refractory metals and alloys' include the following metals and their alloys: niobium (columbium), molybdenum, tungsten and tantalum.

9. 'Sensor window materials', as follows: alumina, silicon, germanium, zinc sulphide, zinc selenide, gallium arsenide, diamond, gallium phosphide, sapphire and the following metal halides: sensor window materials of more than 40 mm diameter for zirconium fluoride and hafnium fluoride.

10. "Technology" for single-step pack cementation of solid airfoils is not controlled by Category 2.

DUAL-USE LIST - CATEGORY 2 - MATERIALS PROCESSING

TABLE - DEPOSITION TECHNIQUES - NOTES

11. 'Polymers', as follows: polyimide, polyester, polysulphide, polycarbonates and polyurethanes.

12. 'Modified zirconia' refers to additions of other metal oxides (e.g., calcia, magnesia, yttria, hafnia, rare earth oxides) to zirconia in order to stabilise certain crystallographic phases and phase compositions. Thermal barrier coatings made of zirconia, modified with calcia or magnesia by mixing or fusion, are not controlled.

13. 'Titanium alloys' refers only to aerospace alloys having an ultimate tensile strength of 900 MPa or more measured at 293 K (20°C).

14. 'Low-expansion glasses' refers to glasses which have a coefficient of thermal expansion of $1 \times 10^{-7} K^{-1}$ or less measured at 293 K (20°C).

15. 'Dielectric layers' are coatings constructed of multi-layers of insulator materials in which the interference properties of a design composed of materials of various refractive indices are used to reflect, transmit or absorb various wavelength bands. Dielectric layers refers to more than four dielectric layers or dielectric/metal "composite" layers.

16. 'Cemented tungsten carbide' does not include cutting and forming tool materials consisting of tungsten carbide/(cobalt, nickel), titanium carbide/(cobalt, nickel), chromium carbide/nickel-chromium and chromium carbide/nickel.

17. "Technology" specially designed to deposit diamond-like carbon on any of the following is not controlled:
magnetic disk drives and heads, equipment for the manufacture of disposables, valves for faucets, acoustic diaphragms for speakers, engine parts for automobiles, cutting tools, punching-pressing dies, office automation equipment, microphones, medical devices or moulds, for casting or moulding of plastics, manufactured from alloys containing less than 5% beryllium.

18. 'Silicon carbide' does not include cutting and forming tool materials.

19. Ceramic substrates, as used in this entry, does not include ceramic materials containing 5% by weight, or greater, clay or cement content, either as separate constituents or in combination.

DUAL-USE LIST - CATEGORY 2 - MATERIALS PROCESSING

TABLE - DEPOSITION TECHNIQUES - TECHNICAL NOTE

Processes specified in Column 1 of the Table are defined as follows:

a. Chemical Vapour Deposition (CVD) is an overlay coating or surface modification coating process wherein a metal, alloy, "composite", dielectric or ceramic is deposited upon a heated substrate. Gaseous reactants are decomposed or combined in the vicinity of a substrate resulting in the deposition of the desired elemental, alloy or compound material on the substrate. Energy for this decomposition or chemical reaction process may be provided by the heat of the substrate, a glow discharge plasma, or "laser" irradiation.

N.B.1 CVD includes the following processes: directed gas flow out-of-pack deposition, pulsating CVD, controlled nucleation thermal deposition (CNTD), plasma enhanced or plasma assisted CVD processes.
N.B.2 Pack denotes a substrate immersed in a powder mixture.
N.B.3 The gaseous reactants used in the out-of-pack process are produced using the same basic reactions and parameters as the pack cementation process, except that the substrate to be coated is not in contact with the powder mixture.

b. Thermal Evaporation-Physical Vapour Deposition (TE-PVD) is an overlay coating process conducted in a vacuum with a pressure less than 0.1 Pa wherein a source of thermal energy is used to vaporize the coating material. This process results in the condensation, or deposition, of the evaporated species onto appropriately positioned substrates.

The addition of gases to the vacuum chamber during the coating process to synthesize compound coatings is an ordinary modification of the process.

The use of ion or electron beams, or plasma, to activate or assist the coating's deposition is also a common modification in this technique. The use of monitors to provide in-process measurement of optical characteristics and thickness of coatings can be a feature of these processes.

Specific TE-PVD processes are as follows:

1. Electron Beam PVD uses an electron beam to heat and evaporate the material which forms the coating;
2. Ion Assisted Resistive Heating PVD employs electrically resistive heating sources in combination with impinging ion beam(s) to produce a controlled and uniform flux of evaporated coating species;
3. "Laser" Vaporization uses either pulsed or continuous wave "laser" beams to vaporize the material which forms the coating;

DUAL-USE LIST - CATEGORY 2 - MATERIALS PROCESSING

TABLE - DEPOSITION TECHNIQUES - TECHNICAL NOTE

Processes specified in Column 1 of the Table - continued:

b. 4. Cathodic Arc Deposition employs a consumable cathode of the material which forms the coating and has an arc discharge established on the surface by a momentary contact of a ground trigger. Controlled motion of arcing erodes the cathode surface creating a highly ionized plasma. The anode can be either a cone attached to the periphery of the cathode, through an insulator, or the chamber. Substrate biasing is used for non line-of-sight deposition.

N.B. This definition does not include random cathodic arc deposition with non-biased substrates.

5. Ion Plating is a special modification of a general TE-PVD process in which a plasma or an ion source is used to ionize the species to be deposited, and a negative bias is applied to the substrate in order to facilitate the extraction of the species from the plasma. The introduction of reactive species, evaporation of solids within the process chamber, and the use of monitors to provide in-process measurement of optical characteristics and thicknesses of coatings are ordinary modifications of the process.

c. Pack Cementation is a surface modification coating or overlay coating process wherein a substrate is immersed in a powder mixture (a pack), that consists of:

1. The metallic powders that are to be deposited (usually aluminium, chromium, silicon or combinations thereof);
2. An activator (normally a halide salt); and
3. An inert powder, most frequently alumina.

The substrate and powder mixture is contained within a retort which is heated to between 1,030 K (757°C) and 1,375 K (1,102°C) for sufficient time to deposit the coating.

d. Plasma Spraying is an overlay coating process wherein a gun (spray torch) which produces and controls a plasma accepts powder or wire coating materials, melts them and propels them towards a substrate, whereon an integrally bonded coating is formed. Plasma spraying constitutes either low pressure plasma spraying or high velocity plasma spraying.

N.B.1 Low pressure means less than ambient atmospheric pressure.

N.B.2 High velocity refers to nozzle-exit gas velocity exceeding 750 m/s calculated at 293 K (20°C) at 0.1 MPa.

e. Slurry Deposition is a surface modification coating or overlay coating process wherein a metallic or ceramic powder with an organic binder is suspended in a liquid and is applied to a substrate by either spraying, dipping or painting, subsequent air or oven drying, and heat treatment to obtain the desired coating.

DUAL-USE LIST - CATEGORY 2 - MATERIALS PROCESSING

TABLE - DEPOSITION TECHNIQUES - TECHNICAL NOTE

Processes specified in Column 1 of the Table - continued:

f. Sputter Deposition is an overlay coating process based on a momentum transfer phenomenon, wherein positive ions are accelerated by an electric field towards the surface of a target (coating material). The kinetic energy of the impacting ions is sufficient to cause target surface atoms to be released and deposited on an appropriately positioned substrate.

N.B.1 The Table refers only to triode, magnetron or reactive sputter deposition which is used to increase adhesion of the coating and rate of deposition and to radio frequency (RF) augmented sputter deposition used to permit vaporisation of non-metallic coating materials.

N.B.2 Low-energy ion beams (less than 5 keV) can be used to activate the deposition.

g. Ion Implantation is a surface modification coating process in which the element to be alloyed is ionized, accelerated through a potential gradient and implanted into the surface region of the substrate. This includes processes in which ion implantation is performed simultaneously with electron beam physical vapour deposition or sputter deposition.

DUAL-USE LIST - CATEGORY 2 - MATERIALS PROCESSING

TABLE - DEPOSITION TECHNIQUES - STATEMENT OF UNDERSTANDING

It is understood that the following technical information, accompanying the table of deposition techniques, is for use as appropriate.

1. "Technology" for pretreatments of the substrates listed in the Table, as follows:
    a. Chemical stripping and cleaning bath cycle parameters, as follows:
        1. Bath composition
            a. For the removal of old or defective coatings, corrosion product or foreign deposits;
            b. For preparation of virgin substrates;
        2. Time in bath;
        3. Temperature of bath;
        4. Number and sequences of wash cycles;
    b. Visual and macroscopic criteria for acceptance of the cleaned part;
    c. Heat treatment cycle parameters, as follows:
        1. Atmosphere parameters, as follows:
            a. Composition of the atmosphere;
            b. Pressure of the atmosphere;
        2. Temperature for heat treatment;
        3. Time of heat treatment;
    d. Substrate surface preparation parameters, as follows:
        1. Grit blasting parameters, as follows:
            a. Grit composition;
            b. Grit size and shape;
            c. Grit velocity;
        2. Time and sequence of cleaning cycle after grit blast;
        3. Surface finish parameters;
        4. Application of binders to promote adhesion;
    e. Masking technique parameters, as follows:
        1. Material of mask;
        2. Location of mask;

2. "Technology" for in situ quality assurance techniques for evaluation of the coating processes listed in the Table, as follows:
    a. Atmosphere parameters, as follows:
        1. Composition of the atmosphere;
        2. Pressure of the atmosphere;
    b. Time parameters;
    c. Temperature parameters;
    d. Thickness parameters;
    e. Index of refraction parameters;
    f. Control of composition;

3. "Technology" for post deposition treatments of the coated substrates listed in the Table, as follows:
    a. Shot peening parameters, as follows:
        1. Shot composition;
        2. Shot size;
        3. Shot velocity;

DUAL-USE LIST - CATEGORY 2 - MATERIALS PROCESSING

TABLE - DEPOSITION TECHNIQUES - STATEMENT OF UNDERSTANDING

3. b. Post shot peening cleaning parameters;
   c. Heat treatment cycle parameters, as follows:
      1. Atmosphere parameters, as follows:
         a. Composition of the atmosphere;
         b. Pressure of the atmosphere;
      2. Time-temperature cycles;
   d. Post heat treatment visual and macroscopic criteria for acceptance of the coated substrates;

4. "Technology" for quality assurance techniques for the evaluation of the coated substrates listed in the Table, as follows:
   a. Statistical sampling criteria;
   b. Microscopic criteria for:
      1. Magnification;
      2. Coating thickness uniformity;
      3. Coating integrity;
      4. Coating composition;
      5. Coating and substrates bonding;
      6. Microstructural uniformity;
   c. Criteria for optical properties assessment (measured as a function of wavelength):
      1. Reflectance;
      2. Transmission;
      3. Absorption;
      4. Scatter;

5. "Technology" and parameters related to specific coating and surface modification processes listed in the Table, as follows:
   a. For Chemical Vapour Deposition (CVD):
      1. Coating source composition and formulation;
      2. Carrier gas composition;
      3. Substrate temperature;
      4. Time-temperature-pressure cycles;
      5. Gas control and part manipulation;
   b. For Thermal Evaporation - Physical Vapour Deposition (PVD):
      1. Ingot or coating material source composition;
      2. Substrate temperature;
      3. Reactive gas composition;
      4. Ingot feed rate or material vaporisation rate;
      5. Time-temperature-pressure cycles;
      6. Beam and part manipulation;
      7. "Laser" parameters, as follows:
         a. Wave length;
         b. Power density;
         c. Pulse length;
         d. Repetition ratio;
         e. Source;

DUAL-USE LIST - CATEGORY 2 - MATERIALS PROCESSING

TABLE - DEPOSITION TECHNIQUES - STATEMENT OF UNDERSTANDING

5. c. For Pack Cementation:
   1. Pack composition and formulation;
   2. Carrier gas composition;
   3. Time-temperature-pressure cycles;

   d. For Plasma Spraying:
   1. Powder composition, preparation and size distributions;
   2. Feed gas composition and parameters;
   3. Substrate temperature;
   4. Gun power parameters;
   5. Spray distance;
   6. Spray angle;
   7. Cover gas composition, pressure and flow rates;
   8. Gun control and part manipulation;

   e. For Sputter Deposition:
   1. Target composition and fabrication;
   2. Geometrical positioning of part and target;
   3. Reactive gas composition;
   4. Electrical bias;
   5. Time-temperature-pressure cycles;
   6. Triode power;
   7. Part manipulation;

   f. For Ion Implantation:
   1. Beam control and part manipulation;
   2. Ion source design details;
   3. Control techniques for ion beam and deposition rate parameters;
   4. Time-temperature-pressure cycles;

   g. For Ion Plating:
   1. Beam control and part manipulation;
   2. Ion source design details;
   3. Control techniques for ion beam and deposition rate parameters;
   4. Time-temperature-pressure cycles;
   5. Coating material feed rate and vaporisation rate;
   6. Substrate temperature;
   7. Substrate bias parameters.

DUAL-USE LIST - CATEGORY 3 - ELECTRONICS

3. A. SYSTEMS, EQUIPMENT AND COMPONENTS

<u>Note 1</u> *The control status of equipment and components described in 3.A., other than those described in 3.A.1.a.3. to 3.A.1.a.10. or 3.A.1.a.12., which are specially designed for or which have the same functional characteristics as other equipment is determined by the control status of the other equipment.*

<u>Note 2</u> *The control status of integrated circuits described in 3.A.1.a.3. to 3.A.1.a.9. or 3.A.1.a.12. which are unalterably programmed or designed for a specific function for another equipment is determined by the control status of the other equipment.*

<u>N.B.</u> *When the manufacturer or applicant cannot determine the control status of the other equipment, the control status of the integrated circuits is determined in 3.A.1.a.3. to 3.A.1.a.9. and 3.A.1.a.12.*
If the integrated circuit is a silicon-based "microcomputer microcircuit" or microcontroller microcircuit described in 3.A.1.a.3. having an operand (data) word length of 8 bit or less, the control status of the integrated circuit is determined in 3.A.1.a.3.

3. A. 1. Electronic components, as follows:

a. General purpose integrated circuits, as follows:

<u>Note 1</u> *The control status of wafers (finished or unfinished), in which the function has been determined, is to be evaluated against the parameters of 3.A.1.a.*

<u>Note 2</u> *Integrated circuits include the following types:*
"Monolithic integrated circuits";
"Hybrid integrated circuits";
"Multichip integrated circuits";
"Film type integrated circuits", including silicon-on-sapphire integrated circuits;
"Optical integrated circuits".

3. A. 1. a. 1. Integrated circuits, designed or rated as radiation hardened to withstand any of the following:

a. A total dose of 5×10^3 Gy (Si) or higher;
b. A dose rate upset of 5×10^6 Gy (Si)/s or higher; <u>or</u>
c. A fluence (integrated flux) of neutrons (1 MeV equivalent) of 5×10^{13} n/cm^2 or higher on silicon, or its equivalent for other materials;

<u>Note</u> *3.A.1.a.1.c. does not apply to Metal Insulator Semiconductors (MIS).*

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3. A. 1. a. 2. "Microprocessor microcircuits", "microcomputer microcircuits", microcontroller microcircuits, storage integrated circuits manufactured from a compound semiconductor, analogue-to-digital converters, digital-to-analogue converters, electro-optical or "optical integrated circuits" designed for "signal processing", field programmable logic devices, neural network integrated circuits, custom integrated circuits for which either the function is unknown or the control status of the equipment in which the integrated circuit will be used is unknown, Fast Fourier Transform (FFT) processors, electrical erasable programmable read-only memories (EEPROMs), flash memories or static random-access memories (SRAMs), having any of the following:

a. Rated for operation at an ambient temperature above 398 K (+125°C);
b. Rated for operation at an ambient temperature below 218 K (-55°C); <u>or</u>
c. Rated for operation over the entire ambient temperature range from 218 K (-55°C) to 398 K (+125°C);

<u>Note</u> *3.A.1.a.2. does not apply to integrated circuits for civil automobile or railway train applications.*

3. A. 1. a. 3. "Microprocessor microcircuits", "micro-computer microcircuits" and microcontroller microcircuits, having any of the following characteristics:

<u>Note</u> *3.A.1.a.3. includes digital signal processors, digital array processors and digital coprocessors.*

a. Deleted
b. Manufactured from a compound semiconductor and operating at a clock frequency exceeding 40 MHz; <u>or</u>
c. More than one data or instruction bus or serial communication port that provides a direct external interconnection between parallel "microprocessor microcircuits" with a transfer rate exceeding 150 Mbyte/s;

3. A. 1. a. 4. Storage integrated circuits manufactured from a compound semiconductor;

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3. A. 1. a. 5. Analogue-to-digital and digital-to-analogue converter integrated circuits, as follows:

a. Analogue-to-digital converters having any of the following:
   1. A resolution of 8 bit or more, but less than 12 bit, with a total conversion time of less than 5 ns;
   2. A resolution of 12 bit with a total conversion time of less than 20 ns;
   3. A resolution of more than 12 bit but equal to or less than 14 bit with a total conversion time of less than 200 ns; or
   4. A resolution of more than 14 bit with a total conversion time of less than 1 microsecond;

b. Digital-to-analogue converters with a resolution of 12 bit or more, and a "settling time" of less than 10 ns;

Technical Note

1. *A resolution of n bit corresponds to a quantisation of 2^n levels.*
2. *Total conversion time is the inverse of the sample rate.*

3. A. 1. a. 6. Electro-optical and "optical integrated circuits" designed for "signal processing" having all of the following:

a. One or more than one internal "laser" diode;
b. One or more than one internal light detecting element; and
c. Optical waveguides;

3. A. 1. a. 7. Field programmable logic devices having any of the following:

a. An equivalent usable gate count of more than 30,000 (2 input gates);
b. A typical "basic gate propagation delay time" of less than 0.1 ns; or
c. A toggle frequency exceeding 133 MHz;

Note *3.A.1.a.7.includes:*
- *Simple Programmable Logic Devices (SPLDs)*
- *Complex Programmable Logic Devices (CPLDs)*
- *Field Programmable Gate Arrays (FPGAs)*
- *Field Programmable Logic Arrays (FPLAs)*
- *Field Programmable Interconnects (FPICs)*

N.B. *Field programmable logic devices are also known as field programmable gate or field programmable logic arrays.*

3. A. 1. a. 8. Deleted

3. A. 1. a. 9. Neural network integrated circuits;

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3. A. 1. a. 10. Custom integrated circuits for which the function is unknown, or the control status of the equipment in which the integrated circuits will be used is unknown to the manufacturer, having any of the following:
   a. More than 1,000 terminals;
   b. A typical "basic gate propagation delay time" of less than 0.1 ns; or
   c. An operating frequency exceeding 3 GHz;

3. A. 1. a. 11. Digital integrated circuits, other than those described in 3.A.1.a.3 to 3.A.1.a.10. and 3.A.1.a.12., based upon any compound semiconductor and having any of the following:
   a. An equivalent gate count of more than 3000 (2 input gates); or
   b. A toggle frequency exceeding 1.2 GHz;

3. A. 1. a. 12. Fast Fourier Transform (FFT) processors having a rated execution time for an N-point complex FFT of less than (N $\log_2$ N)/20,480 ms, where N is the number of points;
Technical Note
When N is equal to 1,024 points, the formula in 3.A.1.a.12. gives an execution time of 500 µs.

3. A. 1. b. Microwave or millimetre wave components, as follows:
1. Electronic vacuum tubes and cathodes, as follows:
Note 1 *3.A.1.b.1. does not control tubes designed or rated for operation in any frequency band which meets all of the following characteristics:*
   a. Does not exceed 31.8 GHz; and
   b. Is "allocated by the ITU" for radio-communications services, but not for radio-determination.

Note 2 *3.A.1.b.1. does not control non-"space-qualified" tubes which meet all of the following characteristics:*
   a. An average output power equal to or less than 50 W; and
   b. Designed or rated for operation in any frequency band which meets all of the following characteristics:
      1. Exceeds 31.8 GHz but does not exceed 43.5 GHz; and
      2. Is "allocated by the ITU" for radio-communications services, but not for radio-determination;

a. Travelling wave tubes, pulsed or continuous wave, as follows:
   1. Operating at frequencies exceeding 31.8 GHz;
   2. Having a cathode heater element with a turn on time to rated RF power of less than 3 seconds;
   3. Coupled cavity tubes, or derivatives thereof, with a "fractional bandwidth" of more than 7% or a peak power exceeding 2.5 kW;

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3. A. 1. b. 1. a. 4. Helix tubes, or derivatives thereof, with any of the following characteristics:
   a. An "instantaneous bandwidth" of more than one octave, and average power (expressed in kW) times frequency (expressed in GHz) of more than 0.5;
   b. An "instantaneous bandwidth" of one octave or less, and average power (expressed in kW) times frequency (expressed in GHz) of more than 1; or
   c. Being"space qualified";

b. Crossed-field amplifier tubes with a gain of more than 17 dB;

c. Impregnated cathodes designed for electronic tubes producing a continuous emission current density at rated operating conditions exceeding 5 A/cm^2;

3. A. 1. b. 2. Microwave monolithic integrated circuits (MMIC) power amplifiers having any of the following:

a. Rated for operation at frequencies exceeding 3.2 GHz up to and including 6 GHz and with an average output power greater than 4W (36 dBm) with a "fractional bandwidth" greater than 15%;

b. Rated for operation at frequencies exceeding 6 GHz up to and including 16 GHz and with an average output power greater than 1W (30 dBm) with a "fractional bandwidth" greater than 10%;

c. Rated for operation at frequencies exceeding 16 GHz up to and including 31.8 GHz and with an average output power greater than 0.8W (29 dBm) with a "fractional bandwidth" greater than 10%;

d. Rated for operation at frequencies exceeding 31.8 GHz up to and including 37.5 GHz;

e. Rated for operation at frequencies exceeding 37.5 GHz up to and including 43.5 GHz and with an average output power greater than 0.25W (24 dBm) with a "fractional bandwidth" greater than 10%; or

f. Rated for operation at frequencies exceeding 43.5 GHz.

Note 1 *3.A.1.b.2. does not control broadcast satellite equipment designed or rated to operate in the frequency range of 40.5 to 42.5 GHz.*

Note 2 *The control status of the MMIC whose operating frequency spans more than one frequency range, as defined by 3.A.1.b.2., is determined by the lowest average output power control threshold.*

Note 3 *Notes 1 and 2 in the chapeau to Category 3 mean that 3.A.1.b.2. does not control MMICs if they are specially designed for other applications, e.g., telecommunications, radar, automobiles.*

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3. A. 1. b. 3. Microwave transistors having any of the following:

a. Rated for operation at frequencies exceeding 3.2 GHz up to and including 6 GHz and having an average output power greater than 60W (47.8 dBm);

b. Rated for operation at frequencies exceeding 6 GHz up to and including 31.8 GHz and having an average output power greater than 20W (43 dBm);

c. Rated for operation at frequencies exceeding 31.8 GHz up to and including 37.5 GHz and having an average output power greater than 0.5W (27 dBm);

d. Rated for operation at frequencies exceeding 37.5 GHz up to and including 43.5 GHz and having an average output power greater than 1W (30 dBm); or

e. Rated for operation at frequencies exceeding 43.5 GHz.

Note *The control status of an item whose operating frequency spans more than one frequency range, as defined by 3.A.1.b.3, is determined by the lowest average output power control threshold.*

3. A. 1. b. 4. Microwave solid state amplifiers and microwave assemblies/modules containing microwave amplifiers having any of the following:

a. Rated for operation at frequencies exceeding 3.2 GHz up to and including 6 GHz and with an average output power greater than 60W (47.8 dBm) with a "fractional bandwidth" greater than 15%;

b. Rated for operation at frequencies exceeding 6 GHz up to and including 31.8 GHz and with an average output power greater than 15W (42 dBm) with a "fractional bandwidth" greater than 10%;

c. Rated for operation at frequencies exceeding 31.8 GHz up to and including 37.5 GHz;

d. Rated for operation at frequencies exceeding 37.5 GHz up to and including 43.5 GHz and with an average output power greater than 1W (30 dBm) with a "fractional bandwidth" greater than 10%;

e. Rated for operation at frequencies exceeding 43.5 GHz; or

f. Rated for operation at frequencies above 3 GHz and having all of the following:

1. An average output power (in watts), P, greater than 150 divided by the maximum operating frequency (in GHz) squared [$P>150\ W*GHz^2/f_{GHz}^2$];
2. A fractional bandwidth of 5% or greater; and
3. Any two sides perpendicular to one another with length d (in cm) equal to or less than 15 divided by the lowest operating frequency in GHz [$d \leq 15cm*GHz/ f_{GHz}$].

N.B. *MMIC power amplifiers should be evaluated against the criteria in 3.A.1.b.2.*

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Note 1 *3.A.1.b.4. does not control broadcast satellite equipment designed or rated to operate in the frequency range of 40.5 to 42.5 GHz.*

Note 2 *The control status of an item whose operating frequency spans more than one frequency range, as defined by 3.A.1.b.4, is determined by the lowest average output power control threshold.*

3. A. 1. b. 5. Electronically or magnetically tunable band-pass or band-stop filters having more than 5 tunable resonators capable of tuning across a 1.5:1 frequency band (f_{max}/f_{min}) in less than 10 μs having any of the following:
a. A band-pass bandwidth of more than 0.5% of centre frequency; or
b. A band-stop bandwidth of less than 0.5% of centre frequency;

6. Deleted

3. A. 1. b. 7. Mixers and converters designed to extend the frequency range of equipment described in 3.A.2.c., 3.A.2.e. or 3.A.2.f. beyond the limits stated therein;

8. Microwave power amplifiers containing tubes controlled by 3.A.1.b. and having all of the following:
a. Operating frequencies above 3 GHz;
b. An average output power density exceeding 80 W/kg; and
c. A volume of less than 400 cm^3;

Note *3.A.1.b.8. does not control equipment designed or rated for operation in any frequency band which is "allocated by the ITU" for radio-communications services, but not for radio-determination.*

3. A. 1. c. Acoustic wave devices, as follows, and specially designed components therefor:

1. Surface acoustic wave and surface skimming (shallow bulk) acoustic wave devices (i.e., "signal processing" devices employing elastic waves in materials), having any of the following:
a. A carrier frequency exceeding 2.5 GHz;
b. A carrier frequency exceeding 1 GHz, but not exceeding 2.5 GHz, and having any of the following:
1. A frequency side-lobe rejection exceeding 55 dB;
2. A product of the maximum delay time and the bandwidth (time in μs and bandwidth in MHz) of more than 100;
3. A bandwidth greater than 250 MHz; or
4. A dispersive delay of more than 10 μs; or

c. A carrier frequency of 1 GHz or less, having any of the following:

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1. A product of the maximum delay time and the bandwidth (time in µs and bandwidth in MHz) of more than 100;
2. A dispersive delay of more than 10 µs; or
3. A frequency side-lobe rejection exceeding 55 dB and a bandwidth greater than 50 MHz;

3. A. 1. c. 2. Bulk (volume) acoustic wave devices (i.e., "signal processing" devices employing elastic waves) which permit the direct processing of signals at frequencies exceeding 1 GHz;

3. Acoustic-optic "signal processing" devices employing interaction between acoustic waves (bulk wave or surface wave) and light waves which permit the direct processing of signals or images, including spectral analysis, correlation or convolution;

3. A. 1. d. Electronic devices and circuits containing components, manufactured from "superconductive" materials specially designed for operation at temperatures below the "critical temperature" of at least one of the "superconductive" constituents, with any of the following:

1. Current switching for digital circuits using "superconductive" gates with a product of delay time per gate (in seconds) and power dissipation per gate (in watts) of less than 10^{-14} J; or
2. Frequency selection at all frequencies using resonant circuits with Q-values exceeding 10,000;

3. A. 1. e. High energy devices, as follows:

1. Batteries and photovoltaic arrays, as follows:

Note *3.A.1.e.1. does not control batteries with volumes equal to or less than 27 cm^3 (e.g., standard C-cells or R14 batteries).*

a. Primary cells and batteries having an energy density exceeding 480 Wh/kg and rated for operation in the temperature range from below 243 K (-30°C) to above 343 K (70°C);

b. Rechargeable cells and batteries having an energy density exceeding 150 Wh/kg after 75 charge/discharge cycles at a discharge current equal to C/5 hours (C being the nominal capacity in ampere hours) when operating in the temperature range from below 253 K (-20°C) to above 333 K (60°C);

Technical Note

Energy density is obtained by multiplying the average power in watts (average voltage in volts times average current in amperes) by the duration of the discharge in hours to 75% of the open circuit voltage divided by the total mass of the cell (or battery) in kg.

c. "Space qualified" and radiation hardened photovoltaic arrays with a specific power exceeding 160 W/m^2 at an operating temperature of 301 K (28°C) under a tungsten illumination of 1 kW/m^2 at 2,800 K (2,527°C);

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3. A. 1. e. 2. High energy storage capacitors, as follows:
   a. Capacitors with a repetition rate of less than 10 Hz (single shot capacitors) having all of the following:
      1. A voltage rating equal to or more than 5 kV;
      2. An energy density equal to or more than 250 J/kg; and
      3. A total energy equal to or more than 25 kJ;

3. A. 1. e. 2. b. Capacitors with a repetition rate of 10 Hz or more (repetition rated capacitors) having all of the following:
      1. A voltage rating equal to or more than 5 kV;
      2. An energy density equal to or more than 50 J/kg;
      3. A total energy equal to or more than 100 J; and
      4. A charge/discharge cycle life equal to or more than 10,000;

3. A. 1. e. 3. "Superconductive" electromagnets and solenoids specially designed to be fully charged or discharged in less than one second, having all of the following:

   Note *3.A.1.e.3. does not control "superconductive" electromagnets or solenoids specially designed for Magnetic Resonance Imaging (MRI) medical equipment.*

   a. Energy delivered during the discharge exceeding 10 kJ in the first second;
   b. Inner diameter of the current carrying windings of more than 250 mm; and
   c. Rated for a magnetic induction of more than 8 T or "overall current density" in the winding of more than 300 A/mm^2;

3. A. 1. f. Rotary input type shaft absolute position encoders having any of the following:
   1. A resolution of better than 1 part in 265,000 (18 bit resolution) of full scale; or
   2. An accuracy better than ± 2.5 seconds of arc.

3. A. 2. General purpose electronic equipment, as follows:

   a. Recording equipment, as follows, and specially designed test tape therefor:
      1. Analogue instrumentation magnetic tape recorders, including those permitting the recording of digital signals (e.g., using a high density digital recording (HDDR) module), having any of the following:
         a. A bandwidth exceeding 4 MHz per electronic channel or track;
         b. A bandwidth exceeding 2 MHz per electronic channel or track and having more than 42 tracks; or
         c. A time displacement (base) error, measured in accordance with applicable IRIG or EIA documents, of less than ± 0.1 μs;

      Note *Analogue magnetic tape recorders specially designed for civilian video purposes are not considered to be instrumentation tape recorders.*

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3. A. 2. a. 2. Digital video magnetic tape recorders having a maximum digital interface transfer rate exceeding 360 Mbit/s;

Note *3.A.2.a.2. does not control digital video magnetic tape recorders specially designed for television recording using a signal format, which may include a compressed signal format, standardised or recommended by the ITU, the IEC, the SMPTE, the EBU, the ETSI or the IEEE for civil television applications.*

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3. A. 2. a. 3. Digital instrumentation magnetic tape data recorders employing helical scan techniques or fixed head techniques, having any of the following:
   a. A maximum digital interface transfer rate exceeding 175 Mbit/s; or
   b. Being "space qualified";

   Note *3.A.2.a.3 does not control analogue magnetic tape recorders equipped with HDDR conversion electronics and configured to record only digital data.*

4. Equipment, having a maximum digital interface transfer rate exceeding 175 Mbit/s, designed to convert digital video magnetic tape recorders for use as digital instrumentation data recorders;

5. Waveform digitisers and transient recorders having all of the following:
   a. Digitising rates equal to or more than 200 million samples per second and a resolution of 10 bits or more; and
   b. A continuous throughput of 2 Gbit/s or more;

   Technical Note
   For those instruments with a parallel bus architecture, the continuous throughput rate is the highest word rate multiplied by the number of bits in a word.
   Continuous throughput is the fastest data rate the instrument can output to mass storage without the loss of any information whilst sustaining the sampling rate and analogue-to-digital conversion.

6. Digital instrumentation data recorders, using magnetic disk storage technique, having all of the following:
   a. Digitizing rate equal to or more than 100 million samples per second and a resolution of 8 bit or more; and
   b. A continuous throughput of 1 Gbit/s or more;

3. A. 2. b. "Frequency synthesiser" "electronic assemblies" having a "frequency switching time" from one selected frequency to another of less than 1 ms;

c. Radio frequency "signal analysers", as follows:
   1. "Signal analysers" capable of analysing any frequencies exceeding 31.8 GHz but less than 37.5 GHz or exceeding 43.5 GHz;
   2. "Dynamic signal analysers" having a "real-time bandwidth" exceeding 500 kHz;

   Note *3.A.2.c.2. does not control those "dynamic signal analysers" using only constant percentage bandwidth filters (also known as octave or fractional octave filters).*

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3. A. 2. d. Frequency synthesised signal generators producing output frequencies, the accuracy and short term and long term stability of which are controlled, derived from or disciplined by the internal master frequency, and having any of the following:

1. A maximum synthesised frequency exceeding 31.8 GHz but not exceeding 43.5 GHz and rated to generate a pulse duration of less than 100 ns;
2. A maximum synthesised frequency exceeding 43.5 GHz;
3. A "frequency switching time" from one selected frequency to another of less than 1 ms; <u>or</u>
4. A single sideband (SSB) phase noise better than $-(126 + 20 \log_{10}F - 20 \log_{10}f)$ in dBc/Hz, where F is the off-set from the operating frequency in Hz and f is the operating frequency in MHz;

<u>*Technical Note*</u>
For the purposes of 3.A.2.d.1., 'pulse duration' is defined as the time interval between the leading edge of the pulse achieving 90% of the peak and the trailing edge of the pulse achieving 10% of the peak.

<u>*Note*</u> *3.A.2.d. does not control equipment in which the output frequency is either produced by the addition or subtraction of two or more crystal oscillator frequencies, or by an addition or subtraction followed by a multiplication of the result.*

3. A. 2. e. Network analysers with a maximum operating frequency exceeding 43.5 GHz;

f. Microwave test receivers having all of the following:

1. A maximum operating frequency exceeding 43.5 GHz; <u>and</u>
2. Being capable of measuring amplitude and phase simultaneously;

g. Atomic frequency standards having any of the following:

1. Long-term stability (aging) less (better) than 1×10^{-11}/month; <u>or</u>
2. Being "space qualified".

<u>*Note*</u> *3.A.2.g.1. does not control non-"space qualified" rubidium standards.*

3. A. 3. Spray cooling thermal management systems employing closed loop fluid handling and reconditioning equipment in a sealed enclosure where a dielectric fluid is sprayed onto electronic components using specially designed spray nozzles that are designed to maintain electronic components within their operating temperature range, and specially designed components therefor.

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3. B. TEST, INSPECTION AND PRODUCTION EQUIPMENT

3. B. 1. Equipment for the manufacturing of semiconductor devices or materials, as follows, and specially designed components and accessories therefor:

a. Equipment designed for epitaxial growth, as follows:

1. Equipment capable of producing any of the following:
   a. A silicon layer with a thickness uniform to less than ± 2.5% across a distance of 200 mm or more; or
   b. A layer of any material other than silicon with a thickness uniform to less than ± 2.5% across a distance of 75 mm or more;
2. Metal organic chemical vapour deposition (MOCVD) reactors specially designed for compound semiconductor crystal growth by the chemical reaction between materials controlled by 3.C.3 or 3.C.4.;
3. Molecular beam epitaxial growth equipment using gas or solid sources;

3. B. 1. b. Equipment designed for ion implantation, having any of the following:

1. A beam energy (accelerating voltage) exceeding 1 MeV;
2. Being specially designed and optimised to operate at a beam energy (accelerating voltage) of less than 2 keV;
3. Direct write capability; or
4. A beam energy of 65 keV or more and a beam current of 45 mA or more for high energy oxygen implant into a heated semiconductor material "substrate";

3. B. 1. c. Anisotropic plasma dry etching equipment, as follows:

1. Equipment with cassette-to-cassette operation and load-locks, and having any of the following:
   a. Designed or optimised to produce critical dimensions of 0.3 µm or less with ±5% 3 sigma precision; or
   b. Designed for generating less than 0.04 particles/cm^2 with a measurable particle size greater than 0.1 µm in diameter;
2. Equipment specially designed for equipment controlled by 3.B.1.e. and having any of the following:
   a. Designed or optimised to produce critical dimensions of 0.3 µm or less with ±5% 3 sigma precision; or
   b. Designed for generating less than 0.04 particles/cm^2 with a measurable particle size greater than 0.1 µm in diameter;

3. B. 1. d. Plasma enhanced CVD equipment, as follows:

1. Equipment with cassette-to-cassette operation and load-locks, and designed according to the manufacturer's specifications or optimised for use in the production of semiconductor devices with critical dimensions of 180 nm or less;

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3. B. 1. d. 2. Equipment specially designed for equipment controlled by 3.B.1.e. and designed according to the manufacturer's specifications or optimised for use in the production of semiconductor devices with critical dimensions of 180 nm or less;

3. B. 1. e. Automatic loading multi-chamber central wafer handling systems, having all of the following:

1. Interfaces for wafer input and output, to which more than two pieces of semiconductor processing equipment are to be connected; and
2. Designed to form an integrated system in a vacuum environment for sequential multiple wafer processing;

Note *3.B.1.e. does not control automatic robotic wafer handling systems not designed to operate in a vacuum environment.*

3. B. 1. f. Lithography equipment, as follows:

1. Align and expose step and repeat (direct step on wafer) or step and scan (scanner) equipment for wafer processing using photo-optical or X-ray methods, having any of the following:
   a. A light source wavelength shorter than 350 nm; or
   b. Capable of producing a pattern with a minimum resolvable feature size of 0.35 µm or less;

   Technical Note

   The minimum resolvable feature size is calculated by the following formula:

$$MRF = \frac{(\text{an exposure light source wavelength in } \mu m) \times (K factor)}{\text{numerical aperture}}$$

where the K factor = 0.7.

MRF = minimum resolvable feature size.

2. Equipment specially designed for mask making or semiconductor device processing using deflected focussed electron beam, ion beam or "laser" beam, having any of the following:
   a. A spot size smaller than 0.2 µm;
   b. Being capable of producing a pattern with a feature size of less than 1 µm; or
   c. An overlay accuracy of better than ± 0.20 µm (3 sigma);

3. B. 1. g. Masks and reticles designed for integrated circuits controlled by 3.A.1.;

h. Multi-layer masks with a phase shift layer.

Note *3.B.1.h. does not control multi-layer masks with a phase shift layer designed for the fabrication of memory devices not controlled by 3.A.1.*

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3. B. 2. "Stored programme controlled" test equipment, specially designed for testing finished or unfinished semiconductor devices, as follows, and specially designed components and accessories therefor:

3. B. 2. a. For testing S-parameters of transistor devices at frequencies exceeding 31.8 GHz;

b. For testing integrated circuits capable of performing functional (truth table) testing at a pattern rate of more than 667 MHz;

<u>Note</u> *3.B.2.b. does not control test equipment specially designed for testing:*

1. *"Electronic assemblies" or a class of "electronic assemblies" for home or entertainment applications;*
2. *Uncontrolled electronic components, "electronic assemblies" or integrated circuits;*
3. *Memories.*

<u>Technical Note</u>

For the purpose of this entry, pattern rate is defined as the maximum frequency of digital operation of a tester. It is therefore equivalent to the highest data rate that a tester can provide in non-multiplexed mode. It is also referred to as test speed, maximum digital frequency or maximum digital speed.

3. B. 2. c. For testing microwave integrated circuits controlled by 3.A.1.b.2.;

3. C. MATERIALS

3. C. 1. Hetero-epitaxial materials consisting of a "substrate" having stacked epitaxially grown multiple layers of any of the following:

a. Silicon;
b. Germanium;
c. Silicon Carbide; <u>or</u>
d. III/V compounds of gallium or indium.

<u>Technical Note</u>

III/V compounds are polycrystalline or binary or complex monocrystalline products consisting of elements of groups IIIA and VA of Mendeleyev's periodic classification table (e.g., gallium arsenide, gallium-aluminium arsenide, indium phosphide).

3. C. 2. Resist materials, as follows, and "substrates" coated with controlled resists:

a. Positive resists designed for semiconductor lithography specially adjusted (optimised) for use at wavelengths below 350 nm ;
b. All resists designed for use with electron beams or ion beams, with a sensitivity of 0.01 μcoulomb/mm^2 or better;
c. All resists designed for use with X-rays, with a sensitivity of 2.5 mJ/mm^2 or better;
d. All resists optimised for surface imaging technologies, including silylated resists.

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Technical Note
Silylation techniques are defined as processes incorporating oxidation of the resist surface to enhance performance for both wet and dry developing.

3. C. 3. Organo-inorganic compounds, as follows:
 a. Organo-metallic compounds of aluminium, gallium or indium having a purity (metal basis) better than 99.999%;
 b. Organo-arsenic, organo-antimony and organo-phosphorus compounds having a purity (inorganic element basis) better than 99.999%.

 Note *3.C.3. only controls compounds whose metallic, partly metallic or non-metallic element is directly linked to carbon in the organic part of the molecule.*

3. C. 4. Hydrides of phosphorus, arsenic or antimony, having a purity better than 99.999%, even diluted in inert gases or hydrogen.

 Note *3.C.4. does not control hydrides containing 20% molar or more of inert gases or hydrogen.*

3. D. SOFTWARE

3. D. 1. "Software" specially designed for the "development" or "production" of equipment controlled by 3.A.1.b. to 3.A.2.g. or 3.B.

3. D. 2. "Software" specially designed for the "use" of any of the following:
 a. Equipment controlled by 3.B.1.a. to f.; or
 b. Equipment controlled by 3.B.2.

3. D. 3. Physics-based simulation "software" specially designed for the "development" of lithographic, etching or deposition processes for translating masking patterns into specific topographical patterns in conductors, dielectrics or semiconductor materials.

Technical Note
'Physics-based' in 3.D.3. means using computations to determine a sequence of physical cause and effect events based on physical properties (e.g., temperature, pressure, diffusion constants and semiconductor materials properties).

Note *Libraries, design attributes or associated data for the design of semiconductor devices or integrated circuits are considered as "technology".*

3. D. 4. "Software" specially designed for the "development" of the equipment controlled by 3.A.3.

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3. E. TECHNOLOGY

3. E. 1. "Technology" according to the General Technology Note for the "development" or "production" of equipment or materials controlled by 3.A, 3.B or 3.C;

<u>Note</u> *3.E.1. does not control "technology" for the "production" of equipment or components controlled by 3.A.3.*

2. "Technology" according to the General Technology Note other than that controlled in 3.E.1. for the "development" or "production" of "microprocessor microcircuits", "micro-computer microcircuits" and microcontroller microcircuits having a "composite theoretical performance" ("CTP") of 530 million theoretical operations per second (Mtops) or more and an arithmetic logic unit with an access width of 32 bits or more.

<u>Note</u> *3.E.1. and 3.E.2. do not control "technology" for the "development" or "production" of integrated circuits controlled by 3.A.1.a.3. to 3.A.1.a.12., having all of the following:*
1. Using "technology" of 0.5 μm or more; <u>and</u>
2. Not incorporating multi-layer structures.
<u>Technical Note</u>
The term multi-layer structures in Note b.2. above does not include devices incorporating a maximum of three metal layers and three polysilicon layers.

3. E. 3. Other "technology" for the "development" or "production" of:

a. Vacuum microelectronic devices;

b. Hetero-structure semiconductor devices such as high electron mobility transistors (HEMT), hetero-bipolar transistors (HBT), quantum well and super lattice devices;
<u>Note</u> *3.E.3.b does not control technology for high electron mobility transistors (HEMT) operating at frequencies lower than 31.8 GHz and hetero-junction bipolar transistors (HBT) operating at frequencies lower than 31.8 GHz.*

c. "Superconductive" electronic devices;
d. Substrates of films of diamond for electronic components;
e. Substrates of silicon-on-insulator (SOI) for integrated circuits in which the insulator is silicon dioxide;
f. Substrates of silicon carbide for electronic components;
g. Electronic vacuum tubes operating at frequencies of 31.8 GHz or higher.

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4. COMPUTERS

Note 1 *Computers, related equipment and "software" performing telecommunications or "local area network" functions must also be evaluated against the performance characteristics of Category 5, Part 1 (Telecommunications).*

Note 2 *Control units which directly interconnect the buses or channels of central processing units, "main storage" or disk controllers are not regarded as telecommunications equipment described in Category 5, Part 1 (Telecommunications).*

N.B. *For the control status of "software" specially designed for packet switching, see Category 5.D.1. (Telecommunications).*

Note 3 *Computers, related equipment and "software" performing cryptographic, cryptanalytic, certifiable multi-level security or certifiable user isolation functions, or which limit electromagnetic compatibility (EMC), must also be evaluated against the performance characteristics in Category 5, Part 2 ("Information Security").*

4. A. SYSTEMS, EQUIPMENT AND COMPONENTS

4. A. 1. Electronic computers and related equipment, as follows, and "electronic assemblies" and specially designed components therefor:

a. Specially designed to have any of the following characteristics:

1. Rated for operation at an ambient temperature below 228 K (-45°C) or above 358 K (85°C);

   Note *4.A.1.a.1. does not apply to computers specially designed for civil automobile or railway train applications.*

2. Radiation hardened to exceed any of the following specifications:

   a. Total Dose 5×10^3 Gy (Si);

   b. Dose Rate Upset 5×10^6 Gy (Si)/s; or

   c. Single Event Upset 1×10^{-7} Error/bit/day;

b. Having characteristics or performing functions exceeding the limits in Category 5, Part 2 ("Information Security").

   Note *4.A.1.b. does not control electronic computers and related equipment when accompanying their user for the user's personal use.*

4. A. 2. Deleted

4. A. 3. "Digital computers", "electronic assemblies", and related equipment therefor, as follows, and specially designed components therefor:

Note 1 *4.A.3. includes the following:*

a. Vector processors;

b. Array processors;

c. Digital signal processors;

d. Logic processors;

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e. Equipment designed for "image enhancement";
f. Equipment designed for "signal processing".

Note 2 *The control status of the "digital computers" and related equipment described in 4.A.3 is determined by the control status of other equipment or systems provided:*
a. The "digital computers" or related equipment are essential for the operation of the other equipment or systems;
b. The "digital computers" or related equipment are not a "principal element" of the other equipment or systems; and
N.B.1 *The control status of "signal processing" or "image enhancement" equipment specially designed for other equipment with functions limited to those required for the other equipment is determined by the control status of the other equipment even if it exceeds the "principal element" criterion.*
N.B.2 *For the control status of "digital computers" or related equipment for telecommunications equipment, see Category 5, Part 1 (Telecommunications).*
c. The "technology" for the "digital computers" and related equipment is determined by 4.E.

4. A. 3. a. Designed or modified for "fault tolerance";

Note *For the purposes of 4.A.3.a., "digital computers" and related equipment are not considered to be designed or modified for "fault tolerance" if they utilise any of the following:*
1. Error detection or correction algorithms in "main storage";
2. The interconnection of two "digital computers" so that, if the active central processing unit fails, an idling but mirroring central processing unit can continue the system's functioning;
3. The interconnection of two central processing units by data channels or by using shared storage to permit one central processing unit to perform other work until the second central processing unit fails, at which time the first central processing unit takes over in order to continue the system's functioning; or
4. The synchronisation of two central processing units by "software" so that one central processing unit recognises when the other central processing unit fails and recovers tasks from the failing unit.

4. A. 3. b. "Digital computers" having a "composite theoretical performance" ("CTP") exceeding 190,000 Mtops;

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4. A. 3. c. "Electronic assemblies" specially designed or modified for enhancing performance by aggregation of "computing elements" ("CEs") so that the "CTP" of the aggregation exceeds the limit in 4.A.3.b.;

<u>Note 1</u> *4.A.3.c. applies only to "electronic assemblies" and programmable interconnections not exceeding the limit in 4.A.3.b. when shipped as unintegrated "electronic assemblies". It does not apply to "electronic assemblies" inherently limited by nature of their design for use as related equipment controlled by 4.A.3.d., or 4.A.3.e.*

<u>Note 2</u> *4.A.3.c. does not control "electronic assemblies" specially designed for a product or family of products whose maximum configuration does not exceed the limit of 4.A.3.b.*

d. Deleted

e. Equipment performing analogue-to-digital conversions exceeding the limits in 3.A.1.a.5;

f. Deleted

g. Equipment specially designed to provide external interconnection of "digital computers" or associated equipment which allows communications at data rates exceeding 1,25 Gbyte/s.

<u>Note</u> *4.A.3.g. does not control internal interconnection equipment (e.g., backplanes, buses), passive interconnection equipment, "network access controllers" or "communications channel controllers".*

4. A. 4. Computers, as follows, and specially designed related equipment, "electronic assemblies" and components therefor:

a. "Systolic array computers";
b. "Neural computers";
c. "Optical computers".

4. B. <u>TEST. INSPECTION AND PRODUCTION EQUIPMENT</u> - None

4. C. <u>MATERIALS</u> – None

4. D. <u>SOFTWARE</u>

<u>Note</u> *The control status of "software" for the "development", "production", or "use" of equipment described in other Categories is dealt with in the appropriate Category. The control status of "software" for equipment described in this Category is dealt with herein.*

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4. D. 1. a. "Software" specially designed or modified for the "development", "production" or "use" of equipment or "software" controlled by 4.A. or 4.D.

b. "Software", other than that controlled by 4.D.1.a., specially designed or modified for the "development" or "production" of:
1. "Digital computers" having a "composite theoretical performance" ("CTP") exceeding 28,000 Mtops; <u>or</u>
2. "Electronic assemblies" specially designed or modified for enhancing performance by aggregation of "computing elements" ("CEs") so that the "CTP" of the aggregation exceeds the limit in 4.D.1.b.1.

2. "Software" specially designed or modified to support "technology" controlled by 4.E.

3. Specific "software", as follows:
a. Operating system "software", "software" development tools and compilers specially designed for "multi-data-stream processing" equipment, in "source code";
b. Deleted
c. "Software" having characteristics or performing functions exceeding the limits in Category 5, Part 2 ("Information Security");
<u>Note</u> *4.D.3.c. does not control "software" when accompanying its user for the user's personal use.*

d. Deleted

4. E. <u>TECHNOLOGY</u>

4. E. 1. a. "Technology" according to the General Technology Note, for the "development", "production" or "use" of equipment or "software" controlled by 4.A. or 4.D.

b. "Technology", other than that controlled by 4.E.1.a., specially designed or modified for the "development" or "production" of:
1. "Digital computers" having a "composite theoretical performance" ("CTP") exceeding 28,000 Mtops; <u>or</u>
2. "Electronic assemblies" specially designed or modified for enhancing performance by aggregation of "computing elements" ("CEs") so that the "CTP" of the aggregation exceeds the limit in 4.E.1.b.1.

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TECHNICAL NOTE ON "COMPOSITE THEORETICAL PERFORMANCE" ("CTP")

Abbreviations used in this Technical Note

"CE"	"computing element" (typically an arithmetic logical unit)
FP	floating point
XP	fixed point
t	execution time
XOR	exclusive OR
CPU	central processing unit
TP	theoretical performance (of a single "CE")
"CTP"	"composite theoretical performance" (multiple "CEs")
R	effective calculating rate
WL	word length
L	word length adjustment
*	multiply

Execution time 't' is expressed in microseconds, TP and "CTP" are expressed in millions of theoretical operations per second (Mtops) and WL is expressed in bits.

Outline of "CTP" calculation method

"CTP" is a measure of computational performance given in Mtops. In calculating the "CTP" of an aggregation of "CEs" the following three steps are required:

1. Calculate the effective calculating rate R for each "CE";
2. Apply the word length adjustment (L) to the effective calculating rate (R), resulting in a Theoretical Performance (TP) for each "CE";
3. If there is more than one "CE", combine the TPs, resulting in a "CTP" for the aggregation.

Details for these steps are given in the following sections.

Note 1 For aggregations of multiple "CEs" which have both shared and unshared memory subsystems, the calculation of "CTP" is completed hierarchically, in two steps: first, aggregate the groups of "CEs" sharing memory; second, calculate the "CTP" of the groups using the calculation method for multiple "CEs" not sharing memory.

Note 2 "CEs" that are limited to input/output and peripheral functions (e.g., disk drive, communication and video display controllers) are not aggregated into the "CTP" calculation.

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TECHNICAL NOTE ON "CTP"

The following table shows the method of calculating the Effective Calculating Rate R for each "CE":

Step 1: The effective calculating rate R

For "CEs" Implementing: Note Every "CE" must be evaluated independently.	Effective calculating Rate, R
XP only (R_{xp})	$\frac{1}{3*(t_{xp\ add})}$ if no add is implemented use: $\frac{1}{(t_{xp\ mult})}$ If neither add nor multiply is implemented use the fastest available arithmetic operation as follows: $\frac{1}{3 * t_{xp}}$ See Notes X & Z
FP only (R_{fp})	$\max \frac{1}{t_{fp\ add}}, \frac{1}{t_{fp\ mult}}$ See Notes X & Y
Both FP and XP (R)	Calculate both R_{xp}, R_{fp}
For simple logic processors not implementing any of the specified arithmetic operations.	$\frac{1}{3 * t_{log}}$ Where t_{log} is the execute time of the XOR, or for logic hardware not implementing the XOR, the fastest simple logic operation. See Notes X & Z
For special logic processors not using any of the specified arithmetic or logic operations.	R = R' * WL/64 Where R' is the number of results per second, WL is the number of bits upon which the logic operation occurs, and 64 is a factor to normalize to a 64 bit operation.

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TECHNICAL NOTE ON "CTP"

Note W For a pipelined "CE" capable of executing up to one arithmetic or logic operation every clock cycle after the pipeline is full, a pipelined rate can be established. The effective calculating rate (R) for such a "CE" is the faster of the pipelined rate or non-pipelined execution rate.

Note X For a "CE" which performs multiple operations of a specific type in a single cycle (e.g., two additions per cycle or two identical logic operations per cycle), the execution time t is given by:

$$t = \frac{\text{cycle time}}{\text{the number of identical operations per machine cycle}}$$

"CEs" which perform different types of arithmetic or logic operations in a single machine cycle are to be treated as multiple separate "CEs" performing simultaneously (e.g., a "CE" performing an addition and a multiplication in one cycle is to be treated as two "CEs", the first performing an addition in one cycle and the second performing a multiplication in one cycle).
If a single "CE" has both scalar function and vector function, use the shorter execution time value.

Note Y For the "CE" that does not implement FP add or FP multiply, but that performs FP divide:

$$R_{fp} = \frac{1}{t_{fpdivide}}$$

If the "CE" implements FP reciprocal but not FP add, FP multiply or FP divide, then

$$R_{fp} = \frac{1}{t_{fpreciprocal}}$$

If none of the specified instructions is implemented, the effective FP rate is 0.

Note Z In simple logic operations, a single instruction performs a single logic manipulation of no more than two operands of given lengths.
In complex logic operations, a single instruction performs multiple logic manipulations to produce one or more results from two or more operands.

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TECHNICAL NOTE ON "CTP"

Note Z

Rates should be calculated for all supported operand lengths considering both pipelined operations (if supported), and non-pipelined operations using the fastest executing instruction for each operand length based on:

1. Pipelined or register-to-register operations. Exclude extraordinarily short execution times generated for operations on a predetermined operand or operands (for example, multiplication by 0 or 1). If no register-to-register operations are implemented, continue with (2).
2. The faster of register-to-memory or memory-to-register operations; if these also do not exist, then continue with (3).
3. Memory-to-memory.

In each case above, use the shortest execution time certified by the manufacturer.

Step 2: TP for each supported operand length WL

Adjust the effective rate R (or R') by the word length adjustment L as follows:

$$TP = R * L,$$
$$\text{where } L = (1/3 + WL/96)$$

Note The word length WL used in these calculations is the operand length in bits. (If an operation uses operands of different lengths, select the largest word length.)

The combination of a mantissa ALU and an exponent ALU of a floating point processor or unit is considered to be one "CE" with a Word Length (WL) equal to the number of bits in the data representation (typically 32 or 64) for purposes of the "CTP" calculation.

This adjustment is not applied to specialized logic processors which do not use XOR instructions. In this case TP = R.

Select the maximum resulting value of TP for:

Each XP-only "CE" (R_{xp});
Each FP-only "CE" (R_{fp});
Each combined FP and XP "CE" (R);
Each simple logic processor not implementing any of the specified arithmetic operations; and
Each special logic processor not using any of the specified arithmetic or logic operations.

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TECHNICAL NOTE ON "CTP"

Step 3: "CTP" for aggregations of "CEs", including CPUs.

For a CPU with a single "CE",
"CTP" = TP
(for "CEs" performing both fixed and floating point operations
$TP = max (TP_{fp}, TP_{xp})$)

"CTP" for aggregations of multiple "CEs" operating simultaneously is calculated as follows:

Note 1 For aggregations that do not allow all of the "CEs" to run simultaneously, the possible combination of "CEs" that provides the largest "CTP" should be used. The TP of each contributing "CE" is to be calculated at its maximum value theoretically possible before the "CTP" of the combination is derived.

N.B. To determine the possible combinations of simultaneously operating "CEs", generate an instruction sequence that initiates operations in multiple "CEs", beginning with the slowest "CE" (the one needing the largest number of cycles to complete its operation) and ending with the fastest "CE". At each cycle of the sequence, the combination of "CEs" that are in operation during that cycle is a possible combination. The instruction sequence must take into account all hardware and/or architectural constraints on overlapping operations.

Note 2 A single integrated circuit chip or board assembly may contain multiple "CEs".

Note 3 Simultaneous operations are assumed to exist when the computer manufacturer claims concurrent, parallel or simultaneous operation or execution in a manual or brochure for the computer.

Note 4 "CTP" values are not to be aggregated for "CE" combinations (inter)connected by "Local Area Networks", Wide Area Networks, I/O shared connections/devices, I/O controllers and any communication interconnection implemented by software.

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TECHNICAL NOTE ON "CTP"

Note 5 "CTP" values must be aggregated for multiple "CEs" specially designed to enhance performance by aggregation, operating simultaneously and sharing memory,- or multiple memory/"CE"- combinations operating simultaneously utilising specially designed hardware.
This aggregation does not apply to "electronic assemblies" described in 4.A.3.c.

$$\text{"CTP"} = TP_1 + C_2 * TP_2 + ... + C_n * TP_n,$$

where the TPs are ordered by value, with TP_1 being the highest, TP_2 being the second highest, ..., and TP_n being the lowest. C_i is a coefficient determined by the strength of the interconnection between "CEs", as follows:

For multiple "CEs" operating simultaneously and sharing memory:

$$C_2 = C_3 = C_4 = ... = C_n = 0.75$$

Note 1 When the "CTP" calculated by the above method does not exceed 194 Mtops, the following formula may be used to calculate C_i:

$$C_i = \frac{0.75}{\sqrt{m}} \qquad (i = 2, ..., n)$$

where m = the number of "CEs" or groups of "CEs" sharing access.

provided:
1. The TP_i of each "CE" or group of "CEs" does not exceed 30 Mtops;
2. The "CEs" or groups of "CEs" share access to main memory (excluding cache memory) over a single channel; and
3. Only one "CE" or group of "CEs" can have use of the channel at any given time.

N.B. This does not apply to items controlled under Category 3.

Note 2 "CEs" share memory if they access a common segment of solid state memory. This memory may include cache memory, main memory or other internal memory. Peripheral memory devices such as disk drives, tape drives or RAM disks are not included.

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TECHNICAL NOTE ON "CTP"

For Multiple "CEs" or groups of "CEs" not sharing memory, interconnected by one or more data channels:

$C_i = 0.75 * k_i$ (i = 2, ... , 32) (see Note below)
$= 0.60 * k_i$ (i = 33, ... , 64)
$= 0.45 * k_i$ (i = 65, ... , 256)
$= 0.30 * k_i$ (i > 256)

The value of C_i is based on the number of "CEs", not the number of nodes.

where k_i = min (S_i/K_r, 1), and
K_r = normalizing factor of 20 MByte/s.
S_i = sum of the maximum data rates (in units of MByte/s) for all data channels connected to the i^{th} "CE" or group of "CEs" sharing memory.

When calculating a C_i for a group of "CEs", the number of the first "CE" in a group determines the proper limit for C_i. For example, in an aggregation of groups consisting of 3 "CEs" each, the 22nd group will contain "CE"$_{64}$, "CE"$_{65}$ and "CE"$_{66}$. The proper limit for C_i for this group is 0.60.

Aggregation (of "CEs" or groups of "CEs") should be from the fastest-to-slowest; i.e.:

$TP_1 \geq TP_2 \geq .... \geq TP_n$, and

in the case of $TP_i = TP_{i+1}$, from the largest to smallest; i.e.:

$C_i \geq C_{i+1}$

Note The k_i factor is not to be applied to "CEs" 2 to 12 if the TP_i of the "CE" or group of "CEs" is more than 50 Mtops; i.e., C_i for "CEs" 2 to 12 is 0.75.

DUAL-USE LIST - CATEGORY 5 - PART 1 - TELECOMMUNICATIONS

Part 1 - TELECOMMUNICATIONS

Note 1 *The control status of components, "lasers", test and "production" equipment and "software" therefor which are specially designed for telecommunications equipment or systems is determined in Category 5, Part 1.*

Note 2 *"Digital computers", related equipment or "software", when essential for the operation and support of telecommunications equipment described in this Category, are regarded as specially designed components, provided they are the standard models customarily supplied by the manufacturer. This includes operation, administration, maintenance, engineering or billing computer systems.*

5. A. 1. SYSTEMS, EQUIPMENT AND COMPONENTS

a. Any type of telecommunications equipment having any of the following characteristics, functions or features:

1. Specially designed to withstand transitory electronic effects or electromagnetic pulse effects, both arising from a nuclear explosion;
2. Specially hardened to withstand gamma, neutron or ion radiation; or
3. Specially designed to operate outside the temperature range from 218 K (-55°C) to 397 K (124°C).

   Note *5.A.1.a.3. applies only to electronic equipment.*

Note *5.A.1.a.2. and 5.A.1.a.3. do not control equipment designed or modified for use on board satellites.*

5. A. 1. b. Telecommunication transmission equipment and systems, and specially designed components and accessories therefor, having any of the following characteristics, functions or features:

1. Being underwater communications systems having any of the following characteristics:
   a. An acoustic carrier frequency outside the range from 20 kHz to 60 kHz;
   b. Using an electromagnetic carrier frequency below 30 kHz; or
   c. Using electronic beam steering techniques;

DUAL-USE LIST - CATEGORY 5 - PART 1 - TELECOMMUNICATIONS

5. A. 1. b. 2. Being radio equipment operating in the 1.5 MHz to 87.5 MHz band and having any of the following characteristics:

a. Incorporating adaptive techniques providing more than 15 dB suppression of an interfering signal; <u>or</u>

b. Having all of the following:

1. Automatically predicting and selecting frequencies and "total digital transfer rates" per channel to optimise the transmission; <u>and</u>

2. Incorporating a linear power amplifier configuration having a capability to support multiple signals simultaneously at an output power of 1 kW or more in the frequency range of 1.5 MHz or more but less than 30 MHz, or 250 W or more in the frequency range of 30 MHz or more but not exceeding 87.5 MHz, over an "instantaneous bandwidth" of one octave or more and with an output harmonic and distortion content of better than -80 dB;

5. A. 1. b. 3. Being radio equipment employing "spread spectrum" techniques, including "frequency hopping" techniques, having any of the following characteristics:

a. User programmable spreading codes; <u>or</u>

b. A total transmitted bandwidth which is 100 or more times the bandwidth of any one information channel and in excess of 50 kHz;

<u>Note</u> *5.A.1.b.3.b. does not control radio equipment specially designed for use with civil cellular radio-communications systems.*

<u>Note</u> *5.A.1.b.3. does not control equipment designed to operate at an output power of 1.0 Watt or less.*

5. A. 1. b. 4. Being radio equipment employing "time-modulated ultra-wideband" techniques, having user programmable channelizing or scrambling codes;

5. A. 1. b. 5. Being digitally controlled radio receivers having all of the following:

a. More than 1,000 channels;

b. A "frequency switching time" of less than 1 ms;

c. Automatic searching or scanning of a part of the electromagnetic spectrum; <u>and</u>

d. Identification of the received signals or the type of transmitter; <u>or</u>

<u>Note</u> *5.A.1.b.5. does not control radio equipment specially designed for use with civil cellular radio-communications systems.*

DUAL-USE LIST - CATEGORY 5 - PART 1 - TELECOMMUNICATIONS

5. A. 1. b. 6. Employing functions of digital "signal processing" to provide voice coding output at rates of less than 2,400 bit/s.

<u>Technical Note</u>

For variable rate voice coding, 5.A.1.b.6. applies to the voice coding output of continuous speech.

5. A. 1. c. Optical fibre communication cables, optical fibres and accessories, as follows:

1. Optical fibres of more than 500 m in length, specified by the manufacturer as being capable of withstanding a proof test tensile stress of 2 x 10^9 N/m^2 or more;

<u>Technical Note</u>

Proof Test: on-line or off-line production screen testing that dynamically applies a prescribed tensile stress over a 0.5 to 3 m length of fibre at a running rate of 2 to 5 m/s while passing between capstans approximately 150 mm in diameter. The ambient temperature is a nominal 293 K and relative humidity 40%. Equivalent national standards may be used for executing the proof test.

2. Optical fibre cables and accessories designed for underwater use.

<u>Note</u> *5.A.1.c.2. does not control standard civil telecommunication cables and accessories.*

<u>N.B.1</u> *For underwater umbilical cables, and connectors therefor, see 8.A.2.a.3.*

<u>N.B.2</u> *For fibre-optic hull penetrators or connectors, see 8.A.2.c.*

5. A. 1. d. "Electronically steerable phased array antennae" operating above 31 GHz.

<u>Note</u> *5.A.1.d. does not control "electronically steerable phased array antennae" for landing systems with instruments meeting ICAO standards covering microwave landing systems (MLS).*

5. B. 1. <u>TEST, INSPECTION AND PRODUCTION EQUIPMENT</u>

5. B. 1. a. Equipment and specially designed components or accessories therefor, specially designed for the "development", "production" or "use" of equipment, functions or features controlled by Category 5 - Part 1.

<u>Note</u> *5.B.1.a. does not control optical fibre characterization equipment.*

5. B. 1. b. Equipment and specially designed components or accessories therefor, specially designed for the "development" of any of the following telecommunication transmission or switching equipment:

1. Equipment employing digital techniques designed to operate at a "total digital transfer rate" exceeding 15 Gbit/s;

<u>Technical Note</u>

For switching equipment the "total digital transfer rate" is measured at the highest speed port or line.

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5. B. 1. b. 2. Equipment employing a "laser" and having any of the following:
- a. A transmission wavelength exceeding 1750 nm;
- b. Performing "optical amplification";
- c. Employing coherent optical transmission or coherent optical detection techniques (also called optical heterodyne or homodyne techniques); or
- d. Employing analogue techniques and having a bandwidth exceeding 2.5 GHz;

  Note *5.B.1.b.2.d. does not control equipment specially designed for the "development" of commercial TV systems.*

3. Equipment employing "optical switching";

4. Radio equipment employing quadrature-amplitude-modulation (QAM) techniques above level 256; or

5. Equipment employing "common channel signalling" operating in non-associated mode of operation.

5. C. 1. MATERIALS - None

5. D. 1. SOFTWARE

5. D. 1. a. "Software" specially designed or modified for the "development", "production" or "use" of equipment, functions or features controlled by Category 5 - Part 1.

b. "Software" specially designed or modified to support "technology" controlled by 5.E.1.

c. Specific "software" as follows:
1. "Software" specially designed or modified to provide characteristics, functions or features of equipment controlled by 5.A.1. or 5.B.1.;
2. Deleted
3. "Software", other than in machine-executable form, specially designed for "dynamic adaptive routing".

DUAL-USE LIST - CATEGORY 5 - PART 1 - TELECOMMUNICATIONS

5. D. 1. d. "Software" specially designed or modified for the "development" of any of the following telecommunication transmission or switching equipment:

1. Equipment employing digital techniques designed to operate at a "total digital transfer rate" exceeding 15 Gbit/s;

   Technical Note

   For switching equipment the "total digital transfer rate" is measured at the highest speed port or line.

2. Equipment employing a "laser" and having any of the following:
   a. A transmission wavelength exceeding 1750 nm; or
   b. Employing analogue techniques and having a bandwidth exceeding 2.5 GHz;

      Note *5.D.1.d.2.b. does not control "software" specially designed or modified for the "development" of commercial TV systems.*

3. Equipment employing "optical switching"; or

4. Radio equipment employing quadrature-amplitude-modulation (QAM) techniques above level 256.

5. E. 1. TECHNOLOGY

5. E. 1. a. "Technology" according to the General Technology Note for the "development", "production" or "use" (excluding operation) of equipment, functions or features or "software" controlled by Category 5 - Part 1.

b. Specific "technologies", as follows:
1. "Required" "technology" for the "development" or "production" of telecommunications equipment specially designed to be used on board satellites;
2. "Technology" for the "development" or "use" of "laser" communication techniques with the capability of automatically acquiring and tracking signals and maintaining communications through exoatmosphere or sub-surface (water) media;
3. "Technology" for the "development" of digital cellular radio base station receiving equipment whose reception capabilities that allow multi-band, multi-channel, multi-mode, multi-coding algorithm or multi-protocol operation can be modified by changes in "software";
4. "Technology" for the "development" of "spread spectrum" techniques, including "frequency hopping" techniques.

c. "Technology" according to the General Technology Note for the "development" or "production" of any of the following telecommunication transmission or switching equipment, functions or features:
1. Equipment employing digital techniques designed to operate at a "total digital transfer rate" exceeding 15 Gbit/s;

   Technical Note

DUAL-USE LIST - CATEGORY 5 - PART 1 - TELECOMMUNICATIONS

For switching equipment the "total digital transfer rate" is measured at the highest speed port or line.