

- 2B207 "Robots", "end-effectors" and control units, other than those specified in 2B007, as follows:
- a. "Robots" or "end-effectors" specially designed to comply with national safety standards applicable to handling high explosives (for example, meeting electrical code ratings for high explosives);
 - b. Control units specially designed for any of the "robots" or "end-effectors" specified in 2B207.a.
- 2B209 Flow forming machines, spin forming machines capable of flow forming functions, other than those specified in 2B009 or 2B109, and mandrels, as follows:
- a. Machines having both of the following characteristics:
 1. Three or more rollers (active or guiding); and
 2. Which, according to the manufacturer's technical specification, can be equipped with "numerical control" units or a computer control;
 - b. Rotor-forming mandrels designed to form cylindrical rotors of inside diameter between 75 mm and 650 mm.
- Note: 2B209.a. includes machines which have only a single roller designed to deform metal plus two auxiliary rollers which support the mandrel, but do not participate directly in the deformation process.*
- 2B219 Centrifugal multiplane balancing machines, fixed or portable, horizontal or vertical, as follows:
- a. Centrifugal balancing machines designed for balancing flexible rotors having a length of 600 mm or more and having all of the following characteristics:
 1. Swing or journal diameter greater than 75 mm;
 2. Mass capability of from 0,9 to 23 kg; and
 3. Capable of balancing speed of revolution greater than 5 000 r.p.m.;

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- b. Centrifugal balancing machines designed for balancing hollow cylindrical rotor components and having all of the following characteristics:
 - 1. Journal diameter greater than 75 mm;
 - 2. Mass capability of from 0,9 to 23 kg;
 - 3. A minimum achievable residual specific unbalance equal to or less than 10 g mm/kg per plane; and
 - 4. Belt drive type.

2B225 Remote manipulators that can be used to provide remote actions in radiochemical separation operations or hot cells, having either of the following characteristics:

- a. A capability of penetrating 0,6 m or more of hot cell wall (through-the-wall operation); or
- b. A capability of bridging over the top of a hot cell wall with a thickness of 0,6 m or more (over-the-wall operation).

Technical Note:

Remote manipulators provide translation of human operator actions to a remote operating arm and terminal fixture. They may be of 'master/slave' type or operated by joystick or keypad.

2B226 Controlled atmosphere (vacuum or inert gas) induction furnaces, other than those specified in 3B001 and 9B001, and power supplies therefor, as follows:

N.B. SEE ALSO 3B001 and 9B001.

- a. Furnaces having all of the following characteristics:
 - 1. Capable of operation above 1 123 K (850°C);
 - 2. Induction coils 600 mm or less in diameter; and
 - 3. Designed for power inputs of 5 kW or more;

Note: 2B226.a. does not control furnaces designed for the processing of semiconductor wafers.

- b. Power supplies, with a specified power output of 5 kW or more, specially designed for furnaces specified in 2B226.a.

2B227 Vacuum or other controlled atmosphere metallurgical melting and casting furnaces and related equipment as follows:

- a. Arc remelt furnaces, arc melt furnaces and arc melt and casting furnaces having both of the following characteristics:
 - 1. Consumable electrode capacities between 1 000 cm³ and 20 000 cm³; and
 - 2. Capable of operating with melting temperatures above 1 973 K (1 700°C);
- b. Electron beam melting furnaces, plasma atomisation furnaces and plasma melting furnaces, having both of the following characteristics:
 - 1. A power of 50 kW or greater; and
 - 2. Capable of operating with melting temperatures above 1 473 K (1 200°C);
- c. Computer control and monitoring systems specially configured for any of the furnaces specified in 2B227.a. or 2B227.b.;
- d. Plasma torches specially designed for furnaces specified in 2B227.b. having both of the following characteristics:
 - 1. Operating at a power greater than 50 kW; and
 - 2. Capable of operating above 1 473 K (1 200°C);
- e. Electron beam guns specially designed for the furnaces specified in 2B227.b. operating at a power greater than 50 kW.

2B228 Rotor fabrication or assembly equipment, rotor straightening equipment, bellows-forming mandrels and dies, as follows:

- a. Rotor assembly equipment for assembly of gas centrifuge rotor tube sections, baffles, and end caps;

Note: 2B228.a. includes precision mandrels, clamps, and shrink fit machines.

- b. Rotor straightening equipment for alignment of gas centrifuge rotor tube sections to a common axis;

Technical Note:

In 2B228.b. such equipment normally consists of precision measuring probes linked to a computer that subsequently controls the action of, for example, pneumatic rams used for aligning the rotor tube sections.

- c. Bellows-forming mandrels and dies for producing single-convolution bellows.

Technical Note:

In 2B228.c. the bellows have all of the following characteristics:

1. *Inside diameter between 75 mm and 650 mm;*
2. *Length equal to or greater than 12,7 mm;*
3. *Single convolution depth greater than 2 mm; and*
4. *Made of high-strength aluminium alloys, maraging steel or high strength "fibrous or filamentary materials".*

2B230 All types of 'pressure transducers' capable of measuring absolute pressures and having all of the following:

- a. Pressure sensing elements made of or protected by aluminium, aluminium alloy, aluminium oxide (alumina or sapphire), nickel, nickel alloy with more than 60% nickel by weight, or fully fluorinated hydrocarbon polymers;
- b. Seals, if any, essential for sealing the pressure sensing element, and in direct contact with the process medium, made of or protected by aluminium, aluminium alloy, aluminium oxide (alumina or sapphire), nickel, nickel alloy with more than 60% nickel by weight, or fully fluorinated hydrocarbon polymers; and
- c. Having either of the following characteristics:
 1. A full scale of less than 13 kPa and an 'accuracy' of better than 1% of full-scale; or
 2. A full scale of 13 kPa or greater and an 'accuracy' of better than 130 Pa when measured at 13 kPa.

Technical Notes:

1. In 2B230 'pressure transducer' means a device that converts a pressure measurement into a signal.
2. For the purposes of 2B230, 'accuracy' includes non-linearity, hysteresis and repeatability at ambient temperature.

2B231 Vacuum pumps having all of the following characteristics:

- a. Input throat size equal to or greater than 380 mm;
- b. Pumping speed equal to or greater than 15 m³/s; and
- c. Capable of producing an ultimate vacuum better than 13 mPa.

Technical Notes:

1. The pumping speed is determined at the measurement point with nitrogen gas or air.
2. The ultimate vacuum is determined at the input of the pump with the input of the pump blocked off.

2B232 High-velocity gun systems (propellant, gas, coil, electromagnetic, and electrothermal types, and other advanced systems) capable of accelerating projectiles to 1,5 km/s or greater.

N.B. SEE ALSO MILITARY GOODS CONTROLS.

2B233 Bellows-sealed scroll-type compressors and bellows-sealed scroll-type vacuum pumps having all of the following:

N.B. SEE ALSO 2B350.i.

- a. Capable of an inlet volume flow rate of 50 m³/h or greater;
- b. Capable of a pressure ratio of 2:1 or greater; and
- c. Having all surfaces that come in contact with the process gas made from any of the following materials:
 1. Aluminium or aluminium alloy;
 2. Aluminium oxide;
 3. Stainless steel;
 4. Nickel or nickel alloy;
 5. Phosphor bronze; or
 6. Fluoropolymers.

2B350 Chemical manufacturing facilities, equipment and components, as follows:

- a. Reaction vessels or reactors, with or without agitators, with total internal (geometric) volume greater than 0,1 m³ (100 litres) and less than 20 m³ (20 000 litres), where all surfaces that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:

N.B. For prefabricated repair assemblies, see 2B350.k.

1. 'Alloys' with more than 25% nickel and 20% chromium by weight;
2. Fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
3. Glass (including vitrified or enamelled coating or glass lining);
4. Nickel or 'alloys' with more than 40% nickel by weight;
5. Tantalum or tantalum 'alloys';
6. Titanium or titanium 'alloys';
7. Zirconium or zirconium 'alloys'; or
8. Niobium (columbium) or niobium 'alloys';

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- b. Agitators designed for use in reaction vessels or reactors specified in 2B350.a.; and impellers, blades or shafts designed for such agitators, where all surfaces of the agitator that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:
 - 1. 'Alloys' with more than 25% nickel and 20% chromium by weight;
 - 2. Fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
 - 3. Glass (including vitrified or enamelled coatings or glass lining);
 - 4. Nickel or 'alloys' with more than 40% nickel by weight;
 - 5. Tantalum or tantalum 'alloys';
 - 6. Titanium or titanium 'alloys';
 - 7. Zirconium or zirconium 'alloys'; or
 - 8. Niobium (columbium) or niobium 'alloys';
- c. Storage tanks, containers or receivers with a total internal (geometric) volume greater than 0,1 m³ (100 litres) where all surfaces that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:

N.B. For prefabricated repair assemblies, see 2B350.k.

- 1. 'Alloys' with more than 25% nickel and 20% chromium by weight;
- 2. Fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
- 3. Glass (including vitrified or enamelled coatings or glass lining);
- 4. Nickel or 'alloys' with more than 40% nickel by weight;
- 5. Tantalum or tantalum 'alloys';
- 6. Titanium or titanium 'alloys';
- 7. Zirconium or zirconium 'alloys'; or
- 8. Niobium (columbium) or niobium 'alloys';

- d. Heat exchangers or condensers with a heat transfer surface area greater than 0,15 m², and less than 20 m²; and tubes, plates, coils or blocks (cores) designed for such heat exchangers or condensers, where all surfaces that come in direct contact with the chemical(s) being processed are made from any of the following materials:
 1. 'Alloys' with more than 25% nickel and 20% chromium by weight;
 2. Fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
 3. Glass (including vitrified or enamelled coatings or glass lining);
 4. Graphite or 'carbon graphite';
 5. Nickel or 'alloys' with more than 40% nickel by weight;
 6. Tantalum or tantalum 'alloys';
 7. Titanium or titanium 'alloys';
 8. Zirconium or zirconium 'alloys';
 9. Silicon carbide;
 10. Titanium carbide; or
 11. Niobium (columbium) or niobium 'alloys';
- e. Distillation or absorption columns of internal diameter greater than 0,1 m; and liquid distributors, vapour distributors or liquid collectors designed for such distillation or absorption columns, where all surfaces that come in direct contact with the chemical(s) being processed are made from any of the following materials:
 1. 'Alloys' with more than 25% nickel and 20% chromium by weight;
 2. Fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
 3. Glass (including vitrified or enamelled coatings or glass lining);
 4. Graphite or 'carbon graphite';
 5. Nickel or 'alloys' with more than 40% nickel by weight;
 6. Tantalum or tantalum 'alloys';
 7. Titanium or titanium 'alloys';
 8. Zirconium or zirconium 'alloys'; or
 9. Niobium (columbium) or niobium 'alloys';

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- f. Remotely operated filling equipment in which all surfaces that come in direct contact with the chemical(s) being processed are made from any of the following materials:
 - 1. 'Alloys' with more than 25% nickel and 20% chromium by weight; or
 - 2. Nickel or 'alloys' with more than 40% nickel by weight;
- g. Valves and components, as follows:
 - 1. Valves, having both of the following:
 - a. A 'nominal size' greater than DN 10 or NPS 3/8; and
 - b. All surfaces that come in direct contact with the chemical(s) being produced, processed, or contained are made from 'corrosion resistant materials';
 - 2. Valves, other than those specified in 2B350.g.1., having all of the following:
 - a. A 'nominal size' equal to or greater than DN 25 or NPS 1 and equal to or less than DN 100 or NPS 4;
 - b. Casings (valve bodies) or preformed casing liners;
 - c. A closure element designed to be interchangeable; and
 - d. All surfaces of the casing (valve body) or preformed case liner that come in direct contact with the chemical(s) being produced, processed, or contained are made from 'corrosion resistant materials';
 - 3. Components, designed for valves specified in 2B350.g.1. or 2B350.g.2., in which all surfaces that come in direct contact with the chemical(s) being produced, processed, or contained are made from 'corrosion resistant materials', as follows:
 - a. Casings (valve bodies);
 - b. Preformed casing liners;

Technical Notes:

1. For the purposes of 2B350.g., 'corrosion resistant materials' means any of the following materials:
 - a. Nickel or alloys with more than 40% nickel by weight;
 - b. Alloys with more than 25% nickel and 20% chromium by weight;
 - c. Fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
 - d. Glass or glass-lined (including vitrified or enamelled coating);
 - e. Tantalum or tantalum alloys;
 - f. Titanium or titanium alloys;
 - g. Zirconium or zirconium alloys;
 - h. Niobium (columbium) or niobium alloys; or
 - i. Ceramic materials as follows:
 1. Silicon carbide with a purity of 80% or more by weight;
 2. Aluminium oxide (alumina) with a purity of 99,9% or more by weight;
 3. Zirconium oxide (zirconia).
2. The 'nominal size' is defined as the smaller of the inlet and outlet diameters.
3. Nominal sizes (DN) of valves are in accordance with ISO 6708:1995. Nominal Pipe Sizes (NPS) are in accordance with ASME B36.10 or B36.19 or national equivalents.
- h. Multi-walled piping incorporating a leak detection port, in which all surfaces that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:
 1. 'Alloys' with more than 25% nickel and 20% chromium by weight;
 2. Fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
 3. Glass (including vitrified or enamelled coatings or glass lining);
 4. Graphite or 'carbon graphite';
 5. Nickel or 'alloys' with more than 40% nickel by weight;
 6. Tantalum or tantalum 'alloys';
 7. Titanium or titanium 'alloys';
 8. Zirconium or zirconium 'alloys'; or
 9. Niobium (columbium) or niobium 'alloys';

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- i. Multiple-seal and seal-less pumps, with manufacturer's specified maximum flow-rate greater than 0,6 m³/hour, or vacuum pumps with manufacturer's specified maximum flow-rate greater than 5 m³/hour (under standard temperature (273 K (0°C)) and pressure (101,3 kPa) conditions), other than those specified in 2B233; and casings (pump bodies), preformed casing liners, impellers, rotors or jet pump nozzles designed for such pumps, in which all surfaces that come in direct contact with the chemical(s) being processed are made from any of the following materials:
 1. 'Alloys' with more than 25% nickel and 20% chromium by weight;
 2. Ceramics;
 3. Ferrosilicon (high silicon iron alloys);
 4. Fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
 5. Glass (including vitrified or enamelled coatings or glass lining);
 6. Graphite or 'carbon graphite';
 7. Nickel or 'alloys' with more than 40% nickel by weight;
 8. Tantalum or tantalum 'alloys';
 9. Titanium or titanium 'alloys';
 10. Zirconium or zirconium 'alloys'; or
 11. Niobium (columbium) or niobium 'alloys';

Technical Note:

In 2B350.i., the term seal refers to only those seals that come into direct contact with the chemical(s) being processed (or are designed to), and provide a sealing function where a rotary or reciprocating drive shaft passes through a pump body.

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- j. Incinerators designed to destroy chemicals specified in entry 1C350, having specially designed waste supply systems, special handling facilities and an average combustion chamber temperature greater than 1 273 K (1 000°C), in which all surfaces in the waste supply system that come into direct contact with the waste products are made from or lined with any of the following materials:
 - 1. 'Alloys' with more than 25% nickel and 20% chromium by weight;
 - 2. Ceramics; or
 - 3. Nickel or 'alloys' with more than 40% nickel by weight;
- k. Prefabricated repair assemblies having metallic surfaces that come in direct contact with the chemical(s) being processed which are made from tantalum or tantalum alloys as follows, and specially designed components therefor:
 - 1. Designed for mechanical attachment to glass-lined reaction vessels or reactors specified in 2B350.a.; or
 - 2. Designed for mechanical attachment to glass-lined storage tanks, containers or receivers specified in 2B350.c.

Note 1: For the purposes of 2B350, the materials used for gaskets, packing, seals, screws, washers or other materials performing a sealing function do not determine the status of control, provided that such components are designed to be interchangeable.

Note 2: For the purposes of 2B350.a to 2B350.i and 2B350.k, the phrase «where all surfaces that come in (or into) direct contact with the chemical(s) are made from» is understood to include all operations with the chemical(s), which are wetting the surfaces concerned: inter alia producing, processing, consuming, containing, storing, and/or transferring.

Technical Notes:

- 1. 'Carbon graphite' is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.
- 2. For the listed materials in the above entries, the term 'alloy' when not accompanied by a specific elemental concentration is understood as identifying those alloys where the identified metal is present in a higher percentage by weight than any other element.

2B351 Toxic gas monitors and monitoring systems and their dedicated detecting components, other than those specified in 1A004, as follows; and detectors; sensor devices; and replaceable sensor cartridges therefor:

- a. Designed for continuous operation and usable for the detection of chemical warfare agents or chemicals specified in 1C350 with a 'minimum detection limit' of less than 0,3 mg/m³; or

Technical Note:

The 'minimum detection limit' of toxic gas monitors or monitoring systems is the lowest detectable concentration of the analyte required to produce a signal greater than three times the standard deviation of the toxic gas monitor's or monitoring system's signal when measuring a blank sample.

In the case of toxic gas monitors or monitoring systems having a deadband or programmed zero suppression, the 'minimum detection limit' is the lowest detectable concentration required to produce a reading.

- b. Designed for the detection of cholinesterase-inhibiting activity.

2B352 Biological manufacturing and handling equipment, as follows:

- a. Containment facilities and related equipment as follows:
 1. Complete containment facilities that meet the criteria for P3 or P4 (BL3, BL4, L3, L4) containment as specified in the WHO Laboratory Biosafety Manual (3rd edition, Geneva, 2004);
 2. Equipment designed for fixed installation in containment facilities specified in 2B352.a., as follows:
 - a. Double-door pass-through decontamination autoclaves;
 - b. Breathing air suit decontamination showers;
 - c. Mechanical-seal or inflatable-seal walkthrough doors;
- b. Fermenters and components as follows:
 1. Fermenters capable of cultivation of "microorganisms" or of live cells for the production of viruses or toxins, without the propagation of aerosols, having a total internal volume of 20 litres or more;
 2. Components designed for fermenters specified in 2B352.b.1. as follows:
 - a. Cultivation chambers designed to be sterilised or disinfected in situ;
 - b. Cultivation chamber holding devices;
 - c. Process control units capable of simultaneously monitoring and controlling two or more fermentation system parameters (e.g., temperature, pH, nutrients, agitation, dissolved oxygen, air flow, foam control);
- c. Centrifugal separators capable of continuous separation, without the propagation of aerosols, having a flow rate greater than 100 litres per hour, as follows:
 1. Centrifugal separators having all of the following characteristics:
 - a. One or more sealing joints within the steam containment area;
 - b. Components of polished stainless steel or titanium;
 - c. Capable of in-situ steam sterilisation in a closed state.
 2. Single-use centrifugal separators, in which all components that come in direct contact with the substances being processed are disposable or single-use.

Technical Notes:

1. For the purposes of 2B352.b. fermenters include bioreactors, single-use (disposable) bioreactors, chemostats and continuous-flow systems.
2. For the purposes of 2B352.b. cultivation chamber holding devices include single-use cultivation chambers with rigid walls.

Technical Note:

Centrifugal separators and single-use centrifugal separators include decanters.

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- d. Cross (tangential) flow filtration equipment and components as follows:
 - 1. Cross (tangential) flow filtration equipment capable of separation of "microorganisms", viruses, toxins or cell cultures having all of the following characteristics:
 - a. A total filtration area equal to or greater than 1 m²; and
 - b. Having any of the following characteristics:
 - 1. Capable of being 'sterilised' or 'disinfected' in-situ; or
 - 2. Using disposable or single-use filtration components;

Technical Note:

In 2B352.d.1.b. 'sterilised' denotes the elimination of all viable microbes from the equipment through the use of either physical (e.g. steam) or chemical agents. 'Disinfected' denotes a process to reduce the number of microorganisms but not usually of bacterial spores, through the use of chemical agents, without necessarily killing or removing all organisms.

Note: 2B352.d. does not control equipment designed for reverse osmosis or for filtration of blood for medical applications (e.g. hemodialysis or plasmapheresis), as specified by the manufacturer.

- 2. Cross (tangential) flow filtration components (e.g. modules, elements, cassettes, cartridges, units or plates) with filtration area equal to or greater than 0,2 m² for each component and designed for use in cross (tangential) flow filtration equipment specified in 2B352.d.;
- e. Steam, gas or vapour sterilisable freeze-drying equipment with a condenser capacity of 10 kg of ice or more in 24 hours and less than 1 000 kg of ice in 24 hours;

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- f. Protective and containment equipment, as follows:
 - 1. Protective full or half suits, or hoods dependent upon a tethered external air supply and operating under positive pressure;
Note: 2B352.f.1. does not control suits designed to be worn with self-contained breathing apparatus.
 - 2. Biocontainment chambers, isolators, or biological safety cabinets having all of the following characteristics, for normal operation:
 - a. Fully enclosed workspace where the operator is separated from the work by a physical barrier;
 - b. Able to operate at negative pressure;
 - c. Means to safely manipulate items in the workspace;
 - d. Supply and exhaust air to and from the workspace is HEPA filtered;

Note 1: 2B352.f.2. includes Class III biosafety cabinets, as described in the latest edition of the WHO Laboratory Biosafety Manual or constructed in accordance with national standards, regulations or guidance.

Note 2: 2B352.f.2. includes any isolator meeting all of the above mentioned characteristics, regardless of its intended use and its designation, except for medical isolators specially designed for barrier nursing or transportation of infected patients.

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- g. Aerosol inhalation equipment designed for aerosol challenge testing with "microorganisms", viruses or "toxins" as follows:
 - 1. Whole-body exposure chambers having a capacity of 1 m³ or more;
 - 2. Nose-only exposure apparatus utilising directed aerosol flow and having capacity for exposure of any of the following:
 - a. 12 or more rodents; or
 - b. 2 or more animals other than rodents;
 - 3. Closed animal restraint tubes designed for use with nose-only exposure apparatus utilising directed aerosol flow;

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- h. Spray drying equipment capable of drying toxins or pathogenic "microorganisms" having all of the following:
 - 1. A water evaporation capacity of $\geq 0,4$ kg/h and ≤ 400 kg/h;
 - 2. The ability to generate a typical mean product particle size of ≤ 10 μm with existing fittings or by minimal modification of the spray-dryer with atomisation nozzles enabling generation of the required particle size; and
 - 3. Capable of being sterilised or disinfected in situ;
- i. Nucleic acid synthesisers or synthesisers and assemblers, which are partly or entirely automated, and designed to generate continuous nucleic acids greater than 0,5 kilobases in length.
- j. Peptide synthesizers that are partly or entirely automated and capable of generating peptides at a 'system synthesis scale' of 1 mmol or greater.

Technical Note:

'System synthesis scale' denotes the maximum amount of peptide (mmol) that can be produced by the instrument using the largest compatible reaction vessels (L). For multiple peptides produced in parallel, this is the sum of the largest compatible reaction vessels (L).

N.B. For chemical reaction vessels or reactors, see 2B350.a.

2B510 Additive manufacturing equipment, designed to produce metal or metal alloy components, having all of the following, and specially designed components therefor:

- a. Having at least one of the following consolidation sources:
 - 1. "Laser";
 - 2. Electron beam; or
 - 3. Electric arc;
- b. Having a controlled process atmosphere of any of the following:
 - 1. Inert gas; or
 - 2. Vacuum (equal to or less than 100 Pa);
- c. Having any of the following 'in-process monitoring' equipment in a 'co-axial configuration' or 'paraxial configuration':
 - 1. Imaging camera with a peak response in the wavelength range exceeding 380 nm but not exceeding 14 000 nm;
 - 2. Pyrometer designed to measure temperatures greater than 1 273,15 K (1 000°C); or
 - 3. Radiometer or spectrometer with a peak response in the wavelength range exceeding 380 nm but not exceeding 3 000 nm; and
- d. A closed loop control system designed to modify the consolidation source parameters, build path, or equipment settings during the build cycle in response to feedback from 'in-process monitoring' equipment specified in 2B510.c.

Technical Notes:

For the purposes of 2B510:

1. *'In-process monitoring', also known as in-situ process monitoring, pertains to the observation and measurement of the additive manufacturing process including electromagnetic, or thermal, emissions from the melt pool.*
2. *'Co-axial configuration', also known as on-axis or inline configuration, pertains to one or more sensors that are mounted in an optical path shared by the "laser" consolidation source.*
3. *'Paraxial configuration' pertains to one or more sensors that are physically mounted onto or integrated into the "laser", electron beam, or electric arc consolidation source component.*
4. *For both 'co-axial configuration' and 'paraxial configuration', the field of view of the sensor(s) is fixed to the moving reference frame of the consolidation source and moves in the same scan trajectories of the consolidation source throughout the build process.*

2C Materials

None.

2D Software

2D001 "Software", other than that specified in 2D002, as follows:

- a. "Software" specially designed or modified for the "development" or "production" of equipment specified in 2A001, 2B001 to 2B009 or 2B510
- b. "Software" specially designed or modified for the "use" of equipment specified in 2A001.c., 2B001 or 2B003 to 2B009.

Note: 2D001 does not control part programming "software" that generates "numerical control" codes for machining various parts.

2D002 "Software" for electronic devices, even when residing in an electronic device or system, enabling such devices or systems to function as a "numerical control" unit, capable of co-ordinating simultaneously more than four axes for "contouring control".

Note 1: 2D002 does not control "software" specially designed or modified for the operation of items not specified in Category 2.

Note 2: 2D002 does not control "software" for items specified in 2B002. For "software" for items specified in 2B002, see 2D001 and 2D003.

Note 3: 2D002 does not control "software" that is exported with, and the minimum necessary for the operation of, items not specified in Category 2.

2D003 "Software", designed or modified for the operation of equipment specified in 2B002, that converts optical design, workpiece measurements and material removal functions into "numerical control" commands to achieve the desired workpiece form.

2D101 "Software" specially designed or modified for the "use" of equipment specified in 2B104, 2B105, 2B109, 2B116, 2B117 or 2B119 to 2B122.

N.B. SEE ALSO 9D004.

2D201 "Software" specially designed for the "use" of equipment specified in 2B204, 2B206, 2B207, 2B209, 2B219 or 2B227.

2D202 "Software" specially designed or modified for the "development", "production" or "use" of equipment specified in 2B201.

Note: 2D202 does not control part programming "software" that generates "numerical control" command codes but does not allow direct use of equipment for machining various parts.

2D351 "Software", other than that specified in 1D003, specially designed for "use" of equipment specified in 2B351.

2D352 "Software" specially designed for nucleic acid assemblers and synthesisers specified in 2B352.i., that is capable of designing and building functional genetic elements from digital sequence data.

2E Technology

2E001 "Technology" according to the General Technology Note for the "development" of equipment or "software" specified in 2A, 2B or 2D.

Note: 2E001 includes "technology" for the integration of probe systems into Coordinate Measuring Machines (CMM) specified in 2B006.a.

2E002 "Technology" according to the General Technology Note for the "production" of equipment specified in 2A or 2B.

2E003 Other "technology", as follows:

a. Not used;

b. "Technology" for metal-working manufacturing processes, as follows:

1. "Technology" for the design of tools, dies or fixtures specially designed for any of the following processes:

a. "Superplastic forming";

b. "Diffusion bonding"; or

c. 'Direct-acting hydraulic pressing';

Technical Note:

For the purposes of 2E003.b.1.c., 'direct-acting hydraulic pressing' is a deformation process which uses a fluid-filled flexible bladder in direct contact with the workpiece.

2. Not used;

N.B. For "technology" for metal-working manufacturing processes for gas turbine engines and components, see 9E003 and the Military Goods Controls.

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- c. "Technology" for the "development" or "production" of hydraulic stretch-forming machines and dies therefor, for the manufacture of airframe structures;
- d. Not used;
- e. "Technology" for the "development" of integration "software" for incorporation of expert systems for advanced decision support of shop floor operations into "numerical control" units;
- f. "Technology" for the application of inorganic overlay coatings or inorganic surface modification coatings (specified in column 3 of the following table) to non-electronic substrates (specified in column 2 of the following table), by processes specified in column 1 of the following table and defined in the Technical Note.

Note: The table and Technical Note appear after entry 2E503.

N.B. This table should be read to specify the "technology" for a particular Coating Process only when the Resultant Coating in column 3 is in a paragraph directly across from the relevant Substrate under column 2. For example, Chemical Vapour Deposition (CVD) coating process technical data are included for the application of silicides to carbon-carbon, ceramic and metal "matrix" "composites" substrates, but are not included for the application of silicides to 'cemented tungsten carbide' (16), 'silicon carbide' (18) substrates. In the second case, the resultant coating is not listed in the paragraph under column 3 directly across from the paragraph under column 2 listing 'cemented tungsten carbide' (16), 'silicon carbide' (18).

2E101 "Technology" according to the General Technology Note for the "use" of equipment or "software" specified in 2B004, 2B009, 2B104, 2B109, 2B116, 2B119 to 2B122 or 2D101.

2E201 "Technology" according to the General Technology Note for the "use" of equipment or "software" specified in 2A225, 2A226, 2B001, 2B006, 2B007.b., 2B007.c., 2B008, 2B009, 2B201, 2B204, 2B206, 2B207, 2B209, 2B225 to 2B233, 2D201 or 2D202.

2E301 "Technology" according to the General Technology Note for the "use" of goods specified in 2B350 to 2B352.

2E503 Other "technology", as follows:

- g. "Technology", not specified elsewhere, for the "development" or "production" of 'coating systems' having all of the following:
 1. Designed to protect ceramic "matrix" "composite" materials specified in 1C007 from corrosion; and
 2. Designed to operate at temperatures exceeding 1 373,15 K (1 100°C).

Technical Note:

For the purposes of 2E503.g, 'coating systems' consist of one or more layers (e.g., bond, interlayer, top coat) of material deposited on the substrate.

TABLE - DEPOSITION TECHNIQUES

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
A. Chemical Vapour Deposition (CVD)	"Superalloys"	Aluminides for internal passages
	Ceramics (19) and Low expansion glasses (14)	Silicides Carbides Dielectric layers (15) Diamond Diamond-like carbon (17)
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Refractory metals Mixtures thereof (4) Dielectric layers (15) Aluminides Alloyed aluminides (2) Boron nitride
	Cemented tungsten carbide (16), Silicon carbide (18)	Carbides Tungsten Mixtures thereof (4) Dielectric layers (15)
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Dielectric layers (15) Diamond Diamond-like carbon (17)
	Sensor window materials (9)	Dielectric layers (15) Diamond Diamond-like carbon (17)

⁸

The numbers in parenthesis refer to the Notes following this Table.

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
B. Thermal-Evaporation Physical Vapour Deposition (TE-PVD)		
B.1. Physical Vapour Deposition (PVD): Electron- Beam (EB-PVD)	"Superalloys"	Alloyed silicides Alloyed aluminides (2) MCrAlX (5) Modified zirconia (12) Silicides Aluminides Mixtures thereof (4)
	Ceramics (19) and Low expansion glasses (14)	Dielectric layers (15)
	Corrosion resistant steel (7)	MCrAlX (5) Modified zirconia (12) Mixtures thereof (4)
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Refractory metals Mixtures thereof (4) Dielectric layers (15) Boron nitride
	Cemented tungsten carbide (16), Silicon carbide (18)	Carbides Tungsten Mixtures thereof (4) Dielectric layers (15)

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Dielectric layers (15) Borides Beryllium
	Sensor window materials (9)	Dielectric layers (15)
	Titanium alloys (13)	Borides Nitrides
B.2. Ion assisted resistive heating Physical Vapour Deposition (PVD) (Ion Plating)	Ceramics (19) and Low-expansion glasses	Dielectric layers (15) Diamond-like carbon (17)
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Dielectric layers (15)
	Cemented tungsten carbide (16), Silicon carbide	Dielectric layers (15)
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Dielectric layers (15)
	Sensor window materials (9)	Dielectric layers (15) Diamond-like carbon (17)

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
B.3. Physical Vapour Deposition (PVD): "Laser" Vaporization	Ceramics (19) and Low expansion glasses (14)	Silicides Dielectric layers (15) Diamond-like carbon (17)
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Dielectric layers (15)
	Cemented tungsten carbide (16), Silicon carbide	Dielectric layers (15)
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Dielectric layers (15)
	Sensor window materials (9)	Dielectric layers (15) Diamond-like carbon (17)
B.4. Physical Vapour Deposition (PVD): Cathodic Arc Discharge	"Superalloys"	Alloyed silicides Alloyed aluminides (2) MCrAlX (5)
	Polymers (11) and Organic "matrix" "composites"	Borides Carbides Nitrides Diamond-like carbon (17)

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
C. Pack cementation (see A above for out-of-pack cementation) (10)	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Mixtures thereof (4)
	Titanium alloys (13)	Silicides Aluminides Alloyed aluminides (2)
	"Refractory metals and alloys"	Silicides Oxides
D. Plasma spraying	"Superalloys"	MCrAlX (5) Modified zirconia (12) Mixtures thereof (4) Abradable Nickel-Graphite Abradable materials containing Ni-Cr-Al Abradable Al-Si-Polyester Alloyed aluminides (2)
	Aluminium alloys (6)	MCrAlX (5) Modified zirconia (12) Silicides Mixtures thereof (4)

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
	"Refractory metals and alloys"	Aluminides Silicides Carbides
	Corrosion resistant steel (7)	MCrAlX (5) Modified zirconia (12) Mixtures thereof (4)
	Titanium alloys (13)	Carbides Aluminides Silicides Alloyed aluminides (2) Abradable Nickel-Graphite Abradable materials containing Ni-Cr-Al Abradable Al-Si-Polyester
E. Slurry Deposition	"Refractory metals and alloys"	Fused silicides Fused aluminides except for resistance heating elements
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Mixtures thereof (4)

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
F. Sputter Deposition	"Superalloys"	Alloyed silicides Alloyed aluminides (2) Noble metal modified aluminides (3) MCrAlX (5) Modified zirconia (12) Platinum Mixtures thereof (4)
	Ceramics and Low-expansion glasses (14)	Silicides Platinum Mixtures thereof (4) Dielectric layers (15) Diamond-like carbon (17)
	Titanium alloys (13)	Borides Nitrides Oxides Silicides Aluminides Alloyed aluminides (2) Carbides

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Refractory metals Mixtures thereof (4) Dielectric layers (15) Boron nitride
	Cemented tungsten carbide (16), Silicon carbide (18)	Carbides Tungsten Mixtures thereof (4) Dielectric layers (15) Boron nitride
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Borides Dielectric layers (15) Beryllium
	Sensor window materials (9)	Dielectric layers (15) Diamond-like carbon (17)
	"Refractory metals and alloys"	Aluminides Silicides Oxides Carbides

1. <u>Coating Process</u> (1)⁸	2. <u>Substrate</u>	3. <u>Resultant Coating</u>
G. Ion Implantation	High temperature bearing steels	Additions of Chromium Tantalum or Niobium (Columbium)
	Titanium alloys (13)	Borides Nitrides
	Beryllium and Beryllium alloys	Borides
	Cemented tungsten carbide (16)	Carbides Nitrides

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% by weight in various proportions and combinations, except:

- a. CoCrAlY coatings which contain less than 22% by weight of chromium, less than 7% by weight of aluminium and less than 2% by weight of yttrium;
 - b. CoCrAlY coatings which contain 22 to 24% by weight of chromium, 10 to 12% by weight of aluminium and 0,5 to 0,7% by weight of yttrium; or
 - c. NiCrAlY coatings which contain 21 to 23% by weight of chromium, 10 to 12% by weight of aluminium and 0,9 to 1,1% by weight 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. Not used.
 - 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. Category 2 does not include "technology" for single-step pack cementation of solid aerofoils.

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 $1 \times 10^{-7} \text{ K}^{-1}$ 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" for depositing 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 or 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.

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 vaporise 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 synthesise 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 Physical Vapour Deposition (EB-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" Vaporisation uses either pulsed or continuous wave "laser" beams to vaporise the material which forms the coating;

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 ionised 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 ionise 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.

- 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 ionised, 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 (EB-PVD) or sputter deposition.

PART V – Category 3

CATEGORY 3 - ELECTRONICS

3A Systems, Equipment and Components

Note 1: The control status of equipment and components described in 3A001, 3A002 or 3A501, other than those described in 3A001.a.3. to 3A001.a.10., 3A001.a.12. to 3A001.a.14., 3A001.b.12. or 3A501.a.15. 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.

Note 2: The control status of integrated circuits described in 3A001.a.3. to 3A001.a.9., or 3A001.a.12. to 3A001.a.14., which are unalterably programmed or designed for a specific function for another equipment is determined by the control status of the other equipment.

N.B. When the manufacturer or applicant cannot determine the control status of the other equipment, the control status of the integrated circuits is determined in 3A001.a.3. to 3A001.a.9., and 3A001.a.12. to 3A001.a.14.

Note 3: The status of wafers (finished or unfinished), in which the function has been determined, is to be evaluated against the parameters of 3A001.a., 3A001.b., 3A001.d., 3A001.e.4., 3A001.g., 3A001.h., or 3A001.i.

3A001 Electronic items as follows:

a. General purpose integrated circuits, as follows:

Note: Integrated circuits include the following types:

- "Monolithic integrated circuits";
- "Hybrid integrated circuits";
- "Multichip integrated circuits";
- 'Film type integrated circuit', including silicon-on-sapphire integrated circuits;
- "Optical integrated circuits";
- 'Three dimensional integrated circuit';
- "Monolithic Microwave Integrated Circuits" ("MMICs").

Technical Notes:

For the purposes of 3A001.a.:

1. 'Film type integrated circuit' is an array of "circuit elements" and metallic interconnections formed by deposition of a thick or thin film on an insulating "substrate".
2. 'Three dimensional integrated circuit' is a collection of semiconductor dies or active device layers, integrated together, and having through semiconductor via connections passing completely through an interposer, substrate, die or layer to establish interconnections between the device layers. An interposer is an interface that enables electrical connections.

3A001.a. continued

1. Integrated circuits designed or rated as radiation hardened to withstand any of the following:
 - a. A total dose of 5×10^3 Gy (silicon) or higher;
 - b. A dose rate upset of 5×10^6 Gy (silicon)/s or higher; or
 - c. A fluence (integrated flux) of neutrons (1 MeV equivalent) of 5×10^{13} n/cm² or higher on silicon, or its equivalent for other materials;

Note: 3A001.a.1.c. does not control Metal Insulator Semiconductors (MIS).

2. "Microprocessor microcircuits", "microcomputer microcircuits", microcontroller microcircuits, storage integrated circuits manufactured from a compound semiconductor, Analogue-to-Digital Converters (ADCs), integrated circuits that contain ADCs and store or process the digitised data, Digital-to-Analogue Converters (DACs), electro-optical or "optical integrated circuits" designed for "signal processing", field programmable logic devices, 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, Static Random Access Memories (SRAMs), or 'non-volatile memories', 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); or
 - c. Rated for operation over the entire ambient temperature range from 218 K (-55°C) to 398 K (125°C);

Note: 3A001.a.2. does not control integrated circuits designed for civil automobiles or railway train applications.

Technical Note:

For the purposes of 3A001.a.2., 'non-volatile memories' are memories with data retention over a period of time after a power shutdown.

N.B. *For cryogenic CMOS integrated circuits not specified in 3A001.a.2., see 3A501.a.15.*

3A001.a. continued

3. "Microprocessor microcircuits", "microcomputer microcircuits" and microcontroller microcircuits, manufactured from a compound semiconductor and operating at a clock frequency exceeding 40 MHz;

Note: 3A001.a.3. includes digital signal processors, digital array processors and digital coprocessors.

4. Not used;
5. Analogue-to-Digital Converter (ADC) and Digital-to-Analogue Converter (DAC) integrated circuits, as follows:

- a. ADCs having any of the following:

N.B. SEE ALSO 3A101

1. Not used;
2. A resolution of 10 bit or more, but less than 12 bit, with a "sample rate" greater than 600 Mega Samples Per Second (MSPS);
3. A resolution of 12 bit or more, but less than 14 bit, with a "sample rate" greater than 400 MSPS;
4. A resolution of 14 bit or more, but less than 16 bit, with a "sample rate" greater than 250 MSPS; or
5. A resolution of 16 bit or more with a "sample rate" greater than 65 MSPS;

N.B. For integrated circuits that contain ADCs and store or process the digitised data, see 3A001.a.14.

Technical Notes:

For the purposes of 3A001.a.5.a.:

1. A resolution of n bit corresponds to a quantisation of 2^n levels.
2. The resolution of the ADC is the number of bits of the digital output that represents the measured analogue input. Effective Number of Bits (ENOB) is not used to determine the resolution of the ADC.
3. For "multiple channel ADCs", the "sample rate" is not aggregated and the "sample rate" is the maximum rate of any single channel.
4. For "interleaved ADCs" or for "multiple channel ADCs" that are specified to have an interleaved mode of operation, the "sample rates" are aggregated and the "sample rate" is the maximum combined total rate of all of the interleaved channels.

3A001.a.5. continued

- b. DACs having any of the following:
 - 1. A resolution of 10 bit or more, but less than 12 bit, with an 'adjusted update rate' exceeding 3 500 MSPS; or
 - 2. A resolution of 12 bit or more and having any of the following:
 - a. An 'adjusted update rate' exceeding 1 250 MSPS but not exceeding 3 500 MSPS, and having any of the following:
 - 1. A settling time less than 9 ns to arrive at or within 0,024% of full scale from a full scale step; or
 - 2. A 'Spurious Free Dynamic Range' (SFDR) greater than 68 dBc (carrier) when synthesising a full scale analogue signal of 100 MHz or the highest full scale analogue signal frequency specified below 100 MHz; or
 - b. An 'adjusted update rate' exceeding 3 500 MSPS;

Technical Notes:

For the purposes of 3A001.a.5.b.:

1. *'Spurious Free Dynamic Range' (SFDR) is defined as the ratio of the RMS value of the carrier frequency (maximum signal component) at the input of the DAC to the RMS value of the next largest noise or harmonic distortion component at its output.*
2. *SFDR is determined directly from the specification table or from the characterisation plots of SFDR versus frequency.*
3. *A signal is defined to be full scale when its amplitude is greater than -3 dBfs (full scale).*
4. *'Adjusted update rate' for DACs:*
 - a. *For conventional (non-interpolating) DACs, the 'adjusted update rate' is the rate at which the digital signal is converted to an analogue signal and the output analogue values are changed by the DAC. For DACs where the interpolation mode may be bypassed (interpolation factor of one), the DAC should be considered as a conventional (non-interpolating) DAC.*
 - b. *For interpolating DACs (oversampling DACs), the 'adjusted update rate' is defined as the DAC update rate divided by the smallest interpolating factor. For interpolating DACs, the 'adjusted update rate' may be referred to by different terms including:*
 - *input data rate*
 - *input word rate*
 - *input sample rate*
 - *maximum total input bus rate*
 - *maximum DAC clock rate for DAC clock input.*

3A001.a. continued

6. Electro-optical and "optical integrated circuits", designed for "signal processing" and 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;
7. Field programmable logic devices having any of the following:
 - a. A maximum number of single-ended digital input/outputs of greater than 700; or
 - b. An 'aggregate one-way peak serial transceiver data rate' of 500 Gb/s or greater;

Note: 3A001.a.7. includes:

- Complex Programmable Logic Devices (CPLDs);
- Field Programmable Gate Arrays (FPGAs);
- Field Programmable Logic Arrays (FPLAs);
- Field Programmable Interconnects (FPICs).

N.B.1 For integrated circuits having field programmable logic devices that are combined with an ADC, see 3A001.a.14.

N.B.2 For "electronic assemblies", modules or equipment, containing one or more 'user configurable' Field Programmable Logic Devices (FPLDs), see 3A502.i.

Technical Notes:

For the purposes of 3A001.a.7.:

1. Maximum number of digital input/outputs in 3A001.a.7.a. is also referred to as the maximum user input/outputs or maximum available input/outputs, whether the integrated circuit is packaged or bare die.
2. 'Aggregate one-way peak serial transceiver data rate' is the product of the peak serial one-way transceiver data rate times the number of transceivers on the FPGA.

3A001.a. continued

8. Not used;
9. Neural network integrated circuits;
N.B. For integrated circuits, having one or more digital processing units having a 'Total Processing Performance' (TPP) of 6 000 or more, see 3A501.a.16.
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 1 500 terminals;
 - b. A typical 'basic gate propagation delay time' of less than 0,02 ns; or
 - c. An operating frequency exceeding 3 GHz;

Technical Notes:

For the purposes of 3A001.a.10.b.:

1. *'Basic gate propagation delay time' is the propagation delay time value corresponding to the basic gate used in a "monolithic integrated circuit". For a 'family' of "monolithic integrated circuits", this may be specified either as the propagation delay time per typical gate within the given 'family' or as the typical propagation delay time per gate within the given 'family'.*
 2. *'Basic gate propagation delay time' is not to be confused with the input/output delay time of a complex "monolithic integrated circuit".*
 3. *'Family' consists of all integrated circuits to which all of the following are applied as their manufacturing methodology and specifications except their respective functions:*
 - a. *The common hardware and software architecture;*
 - b. *The common design and process technology; and*
 - c. *The common basic characteristics.*
11. Digital integrated circuits, other than those described in 3A001.a.3. to 3A001.a.10. and 3A001.a.12., based upon any compound semiconductor and having any of the following:
 - a. An equivalent gate count of more than 3 000 (2 input gates); or
 - b. A toggle frequency exceeding 1,2 GHz;
 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:

For the purposes of 3A001.a.12., when N is equal to 1 024 points, the formula gives an execution time of 500 μ s.

13. Direct Digital Synthesizer (DDS) integrated circuits having any of the following:

- a. A Digital-to-Analogue Converter (DAC) clock frequency of 3,5 GHz or more and a DAC resolution of 10 bit or more, but less than 12 bit; or
- b. A DAC clock frequency of 1,25 GHz or more and a DAC resolution of 12 bit or more;

Technical Note:

For the purposes of 3A001.a.13., the DAC clock frequency may be specified as the master clock frequency or the input clock frequency.

14. Integrated circuits that perform or are programmable to perform all of the following:
 - a. Analogue-to-digital conversions meeting any of the following:
 1. Not used;
 2. A resolution of 10 bit or more, but less than 12 bit, with a "sample rate" greater than 1,0 GSPS;
 3. A resolution of 12 bit or more, but less than 14 bit, with a "sample rate" greater than 1,0 GSPS;
 4. A resolution of 14 bit or more, but less than 16 bit, with a "sample rate" greater than 400 Mega Samples Per Second (MSPS); or
 5. A resolution of 16 bit or more with a "sample rate" greater than 180 MSPS; and
 - b. Any of the following:
 1. Storage of digitised data; or
 2. Processing of digitised data;

N.B.1. For ADC integrated circuits, see 3A001.a.5.a.

N.B.2. For field programmable logic devices, see 3A001.a.7.

Technical Notes:

For the purposes of 3A001.a.14.:

1. A resolution of n bit corresponds to a quantisation of 2^n levels.
2. The resolution of the ADC is the number of bits of the digital output of the ADC that represents the measured analogue input. Effective Number of Bits (ENOB) is not used to determine the resolution of the ADC.
3. For integrated circuits with non-interleaving "multiple channel ADCs", the "sample rate" is not aggregated and the "sample rate" is the maximum rate of any single channel.
4. For integrated circuits with "interleaved ADCs" or with "multiple channel ADCs" that are specified to have an interleaved mode of operation, the "sample rates" are aggregated and the "sample rate" is the maximum combined total rate of all of the interleaved channels.

3A001 continued

- b. Microwave or millimetre wave items as follows:

Technical Note:

For the purposes of 3A001.b., the parameter peak saturated power output may also be referred to on product data sheets as output power, saturated power output, maximum power output, peak power output, or peak envelope power output.

1. "Vacuum electronic devices" and cathodes, as follows:

Note 1: 3A001.b.1. does not control "vacuum electronic devices" designed or rated for operation in any frequency band and having all of the following:

- a. Does not exceed 31,8 GHz; and
- b. Is "allocated by the International Telecommunication Union (ITU)" for radio-communications services, but not for radio-determination.

Note 2: 3A001.b.1. does not control non-"space-qualified" "vacuum electronic devices" having all of the following:

- a. An average output power equal to or less than 50 W; and
- b. Designed or rated for operation in any frequency band and having all of the following:
 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 "vacuum electronic devices", pulsed or continuous wave, as follows:

1. Devices operating at frequencies exceeding 31,8 GHz;
2. Devices having a cathode heater with a turn on time to rated Radio Frequency (RF) power of less than 3 seconds;

3A001.b.1.a. continued

3. Coupled cavity devices, or derivatives thereof, with a "fractional bandwidth" of more than 7% or a peak power exceeding 2,5 kW;
4. Devices based on helix, folded waveguide, or serpentine waveguide circuits, or derivatives thereof, having any of the following:
 - 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;
 - c. Being "space-qualified"; or
 - d. Having a gridded electron gun;
5. Devices with a "fractional bandwidth" greater than or equal to 10%, with any of the following:
 - a. An annular electron beam;
 - b. A non-axisymmetric electron beam; or
 - c. Multiple electron beams;
- b. Crossed-field amplifier "vacuum electronic devices" with a gain of more than 17 dB;
- c. Thermionic cathodes designed for "vacuum electronic devices" producing an emission current density at rated operating conditions exceeding 5 A/cm² or a pulsed (non-continuous) current density at rated operating conditions exceeding 10 A/cm²;
- d. "Vacuum electronic devices" with the capability to operate in a 'dual mode';

Technical Note:

For the purposes of 3A001.b.1.d., 'dual mode' means the "vacuum electronic device" beam current can be intentionally changed between continuous-wave and pulsed mode operation by use of a grid and produces a peak pulse output power greater than the continuous-wave output power.

3A001.b. continued

2. "Monolithic Microwave Integrated Circuits" ("MMIC") amplifiers that are any of the following:

N.B. For "MMIC" amplifiers that have an integrated phase shifter, see 3A001.b.12.

- a. Rated for operation at frequencies exceeding 2,7 GHz up to and including 6,8 GHz with a "fractional bandwidth" greater than 15%, and having any of the following:
 1. A peak saturated power output greater than 75 W (48,75 dBm) at any frequency exceeding 2,7 GHz up to and including 2,9 GHz;
 2. A peak saturated power output greater than 55 W (47,4 dBm) at any frequency exceeding 2,9 GHz up to and including 3,2 GHz;
 3. A peak saturated power output greater than 40 W (46 dBm) at any frequency exceeding 3,2 GHz up to and including 3,7 GHz; or
 4. A peak saturated power output greater than 20 W (43 dBm) at any frequency exceeding 3,7 GHz up to and including 6,8 GHz;

3A001.b.2. continued

- b. Rated for operation at frequencies exceeding 6,8 GHz up to and including 16 GHz with a "fractional bandwidth" greater than 10%, and having any of the following:
 - 1. A peak saturated power output greater than 10 W (40 dBm) at any frequency exceeding 6,8 GHz up to and including 8,5 GHz; or
 - 2. A peak saturated power output greater than 5 W (37 dBm) at any frequency exceeding 8,5 GHz up to and including 16 GHz;
- c. Rated for operation with a peak saturated power output greater than 3 W (34,77 dBm) at any frequency exceeding 16 GHz up to and including 31,8 GHz, and with a "fractional bandwidth" of greater than 10%;
- d. Rated for operation with a peak saturated power output greater than 0,1 nW (-70 dBm) at any frequency exceeding 31,8 GHz up to and including 37 GHz;
- e. Rated for operation with a peak saturated power output greater than 1 W (30 dBm) at any frequency exceeding 37 GHz up to and including 43,5 GHz, and with a "fractional bandwidth" of greater than 10%;
- f. Rated for operation with a peak saturated power output greater than 31,62 mW (15 dBm) at any frequency exceeding 43,5 GHz up to and including 75 GHz, and with a "fractional bandwidth" of greater than 10%;
- g. Rated for operation with a peak saturated power output greater than 10 mW (10 dBm) at any frequency exceeding 75 GHz up to and including 90 GHz, and with a "fractional bandwidth" of greater than 5%; or
- h. Rated for operation with a peak saturated power output greater than 0,1 nW (-70 dBm) at any frequency exceeding 90 GHz;

3A001.b.2. continued

Note 1: Not used.

Note 2: The control status of the "MMIC" whose rated operating frequency includes frequencies listed in more than one frequency range, as defined by 3A001.b.2.a. to 3A001.b.2.h., is determined by the lowest peak saturated power output threshold.

Note 3: Notes 1 and 2 in 3A mean that 3A001.b.2. does not control "MMICs" if they are specially designed for other applications, e.g., telecommunications, radar, automobiles.

3. Discrete microwave transistors that are any of the following:
 - a. Rated for operation at frequencies exceeding 2,7 GHz up to and including 6,8 GHz and having any of the following:
 1. A peak saturated power output greater than 400 W (56 dBm) at any frequency exceeding 2,7 GHz up to and including 2,9 GHz;
 2. A peak saturated power output greater than 205 W (53,12 dBm) at any frequency exceeding 2,9 GHz up to and including 3,2 GHz;
 3. A peak saturated power output greater than 115 W (50,61 dBm) at any frequency exceeding 3,2 GHz up to and including 3,7 GHz; or
 4. A peak saturated power output greater than 60 W (47,78 dBm) at any frequency exceeding 3,7 GHz up to and including 6,8 GHz;

3A001.b.3. continued

- b. Rated for operation at frequencies exceeding 6,8 GHz up to and including 31,8 GHz and having any of the following:
 - 1. A peak saturated power output greater than 50 W (47 dBm) at any frequency exceeding 6,8 GHz up to and including 8,5 GHz;
 - 2. A peak saturated power output greater than 15 W (41,76 dBm) at any frequency exceeding 8,5 GHz up to and including 12 GHz;
 - 3. A peak saturated power output greater than 40 W (46 dBm) at any frequency exceeding 12 GHz up to and including 16 GHz; or
 - 4. A peak saturated power output greater than 7 W (38,45 dBm) at any frequency exceeding 16 GHz up to and including 31,8 GHz;
- c. Rated for operation with a peak saturated power output greater than 0,5 W (27 dBm) at any frequency exceeding 31,8 GHz up to and including 37 GHz;
- d. Rated for operation with a peak saturated power output greater than 1 W (30 dBm) at any frequency exceeding 37 GHz up to and including 43,5 GHz;
- e. Rated for operation with a peak saturated power output greater than 0,1 nW (-70 dBm) at any frequency exceeding 43,5 GHz; or
- f. Other than those specified in 3A001.b.3.a. to 3A001.b.3.e and rated for operation with a peak saturated power output greater than 5 W (37,0 dBm) at all frequencies exceeding 8,5 GHz up to and including 31,8 GHz;

3A001.b.3. continued

Note 1: *The control status of a transistor in 3A001.b.3.a. to 3A001.b.3.e. whose rated operating frequency includes frequencies listed in more than one frequency range, as defined by 3A001.b.3.a. to 3A001.b.3.e., is determined by the lowest peak saturated power output threshold.*

Note 2: *3A001.b.3. includes bare dice, dice mounted on carriers, or dice mounted in packages. Some discrete transistors may also be referred to as power amplifiers, but the status of these discrete transistors is determined by 3A001.b.3.*

3A001.b. continued

4. Microwave solid-state amplifiers and microwave assemblies/modules containing microwave solid-state amplifiers, that are any of the following:
 - a. Rated for operation at frequencies exceeding 2,7 GHz up to and including 6,8 GHz with a "fractional bandwidth" greater than 15%, and having any of the following:
 1. A peak saturated power output greater than 500 W (57 dBm) at any frequency exceeding 2,7 GHz up to and including 2,9 GHz;
 2. A peak saturated power output greater than 270 W (54,3 dBm) at any frequency exceeding 2,9 GHz up to and including 3,2 GHz;
 3. A peak saturated power output greater than 200 W (53 dBm) at any frequency exceeding 3,2 GHz up to and including 3,7 GHz; or
 4. A peak saturated power output greater than 90 W (49,54 dBm) at any frequency exceeding 3,7 GHz up to and including 6,8 GHz;
 - b. Rated for operation at frequencies exceeding 6,8 GHz up to and including 31,8 GHz with a "fractional bandwidth" greater than 10%, and having any of the following:
 1. A peak saturated power output greater than 70 W (48,45 dBm) at any frequency exceeding 6,8 GHz up to and including 8,5 GHz;
 2. A peak saturated power output greater than 50 W (47 dBm) at any frequency exceeding 8,5 GHz up to and including 12 GHz;
 3. A peak saturated power output greater than 30 W (44,77 dBm) at any frequency exceeding 12 GHz up to and including 16 GHz; or
 4. A peak saturated power output greater than 20 W (43 dBm) at any frequency exceeding 16 GHz up to and including 31,8 GHz;

3A001.b.4. continued

- c. Rated for operation with a peak saturated power output greater than 0,5 W (27 dBm) at any frequency exceeding 31,8 GHz up to and including 37 GHz;
- d. Rated for operation with a peak saturated power output greater than 2 W (33 dBm) at any frequency exceeding 37 GHz up to and including 43,5 GHz, and with a "fractional bandwidth" of greater than 10%;
- e. Rated for operation at frequencies exceeding 43,5 GHz and having any of the following:
 - 1. A peak saturated power output greater than 0,2 W (23 dBm) at any frequency exceeding 43,5 GHz up to and including 75 GHz, and with a "fractional bandwidth" of greater than 10%;
 - 2. A peak saturated power output greater than 20 mW (13 dBm) at any frequency exceeding 75 GHz up to and including 90 GHz, and with a "fractional bandwidth" of greater than 5%;
or
 - 3. A peak saturated power output greater than 0,1 nW (-70 dBm) at any frequency exceeding 90 GHz;
- f. Not used;

N.B.1. For "MMIC" amplifiers, see 3A001.b.2.

N.B.2. For 'transmit/receive modules' and 'transmit modules', see 3A001.b.12.

N.B.3. For converters and harmonic mixers, designed to extend the operating or frequency range of signal analysers, signal generators, network analysers or microwave test receivers, see 3A001.b.7.

3A001.b.4. continued

Note 1: Not used.

Note 2: The control status of an item whose rated operating frequency includes frequencies listed in more than one frequency range, as defined by 3A001.b.4.a. to 3A001.b.4.e., is determined by the lowest peak saturated power output threshold.

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 and 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. Not used;
7. Converters and harmonic mixers that are any of the following:
 - a. Designed to extend the frequency range of "signal analysers" beyond 110 GHz;
 - b. Designed to extend the operating range of signal generators as follows:
 1. Beyond 110 GHz;
 2. To an output power greater than 100 mW (20 dBm) anywhere within the frequency range exceeding 43,5 GHz but not exceeding 110 GHz;

3A001.b.7. continued

- c. Designed to extend the operating range of network analysers as follows:
 - 1. Beyond 110 GHz;
 - 2. To an output power greater than 100 mW (20 dBm) anywhere within the frequency range exceeding 43,5 GHz but not exceeding 110 GHz;
 - 3. Not used;
- d. Designed to extend the frequency range of microwave test receivers beyond 110 GHz;

3A001.b. continued

8. Microwave power amplifiers containing "vacuum electronic devices" specified in 3A001.b.1. and having all of the following:
 - a. Operating frequencies above 3 GHz;
 - b. An average output power to mass ratio exceeding 80 W/kg; and
 - c. A volume of less than 400 cm³;

Note: 3A001.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.

9. Microwave power modules (MPM) consisting of, at least, a travelling wave "vacuum electronic device", a "monolithic microwave integrated circuit" ("MMIC") and an integrated electronic power conditioner and having all of the following:
 - a. A 'turn-on time' from off to fully operational in less than 10 seconds;
 - b. A volume less than the maximum rated power in Watts multiplied by 10 cm³/W; and
 - c. An "instantaneous bandwidth" greater than 1 octave ($f_{\max} > 2f_{\min}$) and having any of the following:
 1. For frequencies equal to or less than 18 GHz, an RF output power greater than 100 W; or
 2. A frequency greater than 18 GHz;

Technical Notes:

1. *For the purposes of 3A001.b.9.a. the 'turn-on time' refers to the time from fully-off to fully operational, i.e., it includes the warm-up time of the MPM.*
2. *For the purposes of 3A001.b.9.b., the following example is provided to calculate the volume: for a maximum rated power of 20 W, the volume would be: $20 \text{ W} \times 10 \text{ cm}^3/\text{W} = 200 \text{ cm}^3$.*

3A001.b. continued

10. Oscillators or oscillator assemblies, specified to operate with a Single Sideband (SSB) phase noise, in dBc/Hz, less (better) than $-(126 + 20\log_{10}F - 20\log_{10}f)$ anywhere within the range of $10 \text{ Hz} \leq F \leq 10 \text{ kHz}$;

Technical Note:

For the purposes of 3A001.b.10., F is the offset from the operating frequency in Hz and f is the operating frequency in MHz.

11. 'Frequency synthesizer' 'electronic assemblies' having a 'frequency switching time' as specified in any of the following:
- Less than 143 ps;
 - Less than 100 μs for any frequency change exceeding 2,2 GHz within the synthesised frequency range exceeding 4,8 GHz but not exceeding 31,8 GHz;
 - Not used;
 - Less than 500 μs for any frequency change exceeding 550 MHz within the synthesised frequency range exceeding 31,8 GHz but not exceeding 37 GHz;
 - Less than 100 μs for any frequency change exceeding 2,2 GHz within the synthesised frequency range exceeding 37 GHz but not exceeding 75 GHz;
 - Less than 100 μs for any frequency change exceeding 5,0 GHz within the synthesised frequency range exceeding 75 GHz but not exceeding 90 GHz; or
 - Less than 1 ms within the synthesised frequency range exceeding 90 GHz;

Technical Note:

For the purposes of 3A001.b.11., a 'frequency synthesizer' is any kind of frequency source, regardless of the actual technique used, providing a multiplicity of simultaneous or alternative output frequencies, from one or more outputs, controlled by, derived from or disciplined by a lesser number of standard (or master) frequencies.

N.B. *For general purpose "signal analysers", signal generators, network analysers and microwave test receivers, see 3A002.c., 3A002.d., 3A002.e. and 3A002.f., respectively.*

3A001.b. continued

12. 'Transmit/receive modules', 'transmit/receive MMICs', 'transmit modules', and 'transmit MMICs', rated for operation at frequencies above 2,7 GHz and having all of the following:
 - a. A peak saturated power output (in watts), P_{sat} , greater than 505,62 divided by the maximum operating frequency (in GHz) squared [$P_{\text{sat}} > 505,62 \text{ W} \times \text{GHz}^2 / f_{\text{GHz}}^2$] for any channel;
 - b. A "fractional bandwidth" of 5% or greater for any channel;
 - c. Any planar side with length d (in cm) equal to or less than 15 divided by the lowest operating frequency in GHz [$d \leq 15 \text{ cm} \times \text{GHz} \times N / f_{\text{GHz}}$] where N is the number of transmit or transmit/receive channels; and
 - d. An electronically variable phase shifter per channel.

Technical Notes:

For the purposes of 3A001.b.12.:

1. A 'transmit/receive module' is a multifunction "electronic assembly" that provides bi-directional amplitude and phase control for transmission and reception of signals.
2. A 'transmit module' is an "electronic assembly" that provides amplitude and phase control for transmission of signals.
3. A 'transmit/receive MMIC': is a multifunction "MMIC" that provides bi-directional amplitude and phase control for transmission and reception of signals.
4. A 'transmit MMIC' is a "MMIC" that provides amplitude and phase control for transmission of signals.
5. 2,7 GHz should be used as the lowest operating frequency (f_{GHz}) in the formula in 3A001.b.12.c. for transmit/receive or transmit modules that have a rated operation range extending downward to 2,7 GHz and below [$d \leq 15 \text{ cm} \times \text{GHz} \times N / 2,7 \text{ GHz}$].
6. 3A001.b.12. applies to 'transmit/receive modules' or 'transmit modules' with or without a heat sink. The value of d in 3A001.b.12.c. does not include any portion of the 'transmit/receive module' or 'transmit module' that functions as a heat sink.
7. 'Transmit/receive modules', or 'transmit modules', or 'transmit/receive MMICs' or 'transmit MMICs' may or may not have N integrated radiating antenna elements where N is the number of transmit or transmit/receive channels.

3A001 continued

- c. Acoustic wave devices as follows and specially designed components therefor:
 - 1. Surface acoustic wave and surface skimming (shallow bulk) acoustic wave devices, having any of the following:
 - a. A carrier frequency exceeding 6 GHz;
 - b. A carrier frequency exceeding 1 GHz but not exceeding 6 GHz and having any of the following:
 - 1. A 'frequency side-lobe rejection' exceeding 65 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 and having any of the following:
 - 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 65 dB and a bandwidth greater than 100 MHz;

Technical Note:

For the purposes of 3A001.c.1., 'frequency side-lobe rejection' is the maximum rejection value specified in data sheet.

3A001.c. continued

2. Bulk (volume) acoustic wave devices which permit the direct processing of signals at frequencies exceeding 6 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;

Note: 3A001.c. does not control acoustic wave devices that are limited to a single band pass, low pass, high pass or notch filtering, or resonating function.

- 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 and having 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;
- e. High energy devices as follows:
 1. 'Cells' as follows:
 - a. 'Primary cells' having any of the following at 20°C;
 1. 'Energy density' exceeding 550 Wh/kg and a 'continuous power density' exceeding 50 W/kg; or
 2. 'Energy density' exceeding 50 Wh/kg and a 'continuous power density' exceeding 350 W/kg; or
 - b. 'Secondary cells' having an 'energy density' exceeding 500 Wh/kg at 20°C;

Technical Notes:

1. *For the purposes of 3A001.e.1., 'energy density' (Wh/kg) is calculated from the nominal voltage multiplied by the nominal capacity in ampere-hours (Ah) divided by the mass in kilograms. If the nominal capacity is not stated, energy density is calculated from the nominal voltage squared then multiplied by the discharge duration in hours divided by the discharge load in ohms and the mass in kilograms.*
2. *For the purposes of 3A001.e.1., a 'cell' is defined as an electrochemical device, which has positive and negative electrodes, an electrolyte, and is a source of electrical energy. It is the basic building block of a battery.*
3. *For the purposes of 3A001.e.1.a., a 'primary cell' is a 'cell' that is not designed to be charged by any other source.*
4. *For the purposes of 3A001.e.1.b., a 'secondary cell' is a 'cell' that is designed to be charged by an external electrical source.*
5. *For the purposes of 3A001.e.1.a., 'continuous power density' (W/kg) is calculated from the nominal voltage multiplied by the specified maximum continuous discharge current in amperes (A) divided by the mass in kilograms. 'Continuous power density' is also referred to as specific power.*

Note: 3A001.e.1. does not control batteries, including single-cell batteries.

3A001.e. continued

2. High energy storage capacitors as follows:

N.B. SEE ALSO 3A201.a. and the Military Goods Controls.

a. Capacitors with a repetition rate of less than 10 Hz (single shot capacitors) and 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;

b. Capacitors with a repetition rate of 10 Hz or more (repetition rated capacitors) and 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. "Superconductive" electromagnets and solenoids, specially designed to be fully charged or discharged in less than one second and having all of the following:

N.B. SEE ALSO 3A201.b.

Note: 3A001.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/mm²;

Technical Note:

For the purposes of 3A001.e.3.c., 'overall current density' is the total number of ampere-turns in the coil (i.e., the sum of the number of turns multiplied by the maximum current carried by each turn) divided by the total cross-section of the coil (comprising the superconducting filaments, the metallic matrix in which the superconducting filaments are embedded, the encapsulating material, any cooling channels, etc.).

3A001.e. continued

4. Solar cells, cell-interconnect-coverglass (CIC) assemblies, solar panels, and solar arrays, which are "space-qualified", having a minimum average efficiency exceeding 20% at an operating temperature of 301 K (28°C) under simulated 'AM0' illumination with an irradiance of 1 367 watts per square metre (W/m²);

Technical Note:

For the purposes of 3A001.e.4., 'AM0', or 'Air Mass Zero', refers to the spectral irradiance of sun light in the earth's outer atmosphere when the distance between the earth and sun is one astronomical unit (AU).

- f. Rotary input type absolute position encoders having an "accuracy" equal to or less (better) than 1,0 second of arc and specially designed encoder rings, discs or scales therefor;

N.B. SEE ALSO 3A501.f.

- g. Solid-state pulsed power switching thyristor devices and 'thyristor modules', using either electrically, optically, or electron radiation controlled switch methods and having any of the following:
 1. A maximum turn-on current rate of rise (di/dt) greater than 30 000 A/μs and off-state voltage greater than 1 100 V; or
 2. A maximum turn-on current rate of rise (di/dt) greater than 2 000 A/μs and having all of the following:
 - a. An off-state peak voltage equal to or greater than 3 000 V; and
 - b. A peak (surge) current equal to or greater than 3 000 A.

3A001.g. continued

Note 1: 3A001.g. includes:

- Silicon Controlled Rectifiers (SCRs);
- Electrical Triggering Thyristors (ETTs);
- Light Triggering Thyristors (LTTs);
- Integrated Gate Commutated Thyristors (IGCTs);
- Gate Turn-off Thyristors (GTOs);
- Metal Oxide Semiconductor (MOS) Controlled Thyristors (MCTs);
- Solidtrons.

Note 2: 3A001.g. does not control thyristor devices and 'thyristor modules' incorporated into equipment designed for civil railway or "civil aircraft" applications.

Technical Note:

For the purposes of 3A001.g., a 'thyristor module' contains one or more thyristor devices.

- h. Solid-state power semiconductor switches, diodes, or 'modules', having all of the following:
1. Rated for a maximum operating junction temperature greater than 488 K (215°C);
 2. Repetitive peak off-state voltage (blocking voltage) exceeding 300 V;
and
 3. Continuous current greater than 1 A.

Note 1: Repetitive peak off-state voltage in 3A001.h. includes drain to source voltage, collector to emitter voltage, repetitive peak reverse voltage and peak repetitive off-state blocking voltage.

Note 2: 3A001.h. includes:

- Junction Field Effect Transistors (JFETs);
- Vertical Junction Field Effect Transistors (VJFETs);
- Metal Oxide Semiconductor Field Effect Transistors (MOSFETs);
- Double Diffused Metal Oxide Semiconductor Field Effect Transistor (DMOSFET);
- Insulated Gate Bipolar Transistor (IGBT);
- High Electron Mobility Transistors (HEMTs);
- Bipolar Junction Transistors (BJTs);
- Thyristors and Silicon Controlled Rectifiers (SCRs);
- Gate Turn-Off Thyristors (GTOs);
- Emitter Turn-Off Thyristors (ETOs);
- PiN Diodes;
- Schottky Diodes.

3A001.h. continued

Note 3: 3A001.h. does not control switches, diodes, or 'modules', incorporated into equipment designed for civil automobile, civil railway or "civil aircraft" applications.

Technical Note:

For the purposes of 3A001.h., 'modules' contain one or more solid-state power semiconductor switches or diodes.

- i. Intensity, amplitude, or phase electro-optic modulators, designed for analogue signals and having any of the following:
 1. A maximum operating frequency of more than 10 GHz but less than 20 GHz, an optical insertion loss equal to or less than 3 dB and having any of the following:
 - a. A 'half-wave voltage' ($V\pi$) less than 2,7 V when measured at a frequency of 1 GHz or below; or
 - b. A $V\pi$ of less than 4 V when measured at a frequency of more than 1 GHz; or
 2. A maximum operating frequency equal to or greater than 20 GHz, an optical insertion loss equal to or less than 3 dB and having any of the following:
 - a. A $V\pi$ less than 3,3 V when measured at a frequency of 1 GHz or below; or
 - b. A $V\pi$ less than 5 V when measured at a frequency of more than 1 GHz.

Note: 3A001.i. includes electro-optic modulators having optical input and output connectors (e.g., fibre-optic pigtails).

Technical Note:

For the purposes of 3A001.i., a 'half-wave voltage' ($V\pi$) is the applied voltage necessary to make a phase change of 180 degrees in the wavelength of light propagating through the optical modulator.

N.B. SEE ALSO 3A501.h.

3A002 General purpose "electronic assemblies", modules and equipment, as follows:

- a. Recording equipment and oscilloscopes as follows:
 - 1. Not used;
 - 2. Not used;
 - 3. Not used;
 - 4. Not used;
 - 5. Not used;
 - 6. Digital data recorders having all of the following:
 - a. A sustained 'continuous throughput' of more than 6,4 Gbit/s to disk or solid-state drive memory; and
 - b. "Signal processing" of the radio frequency signal data while it is being recorded;

Technical Notes:

For the purposes of 3A002.a.6.:

- 1. *For recorders with a parallel bus architecture, the 'continuous throughput' rate is the highest word rate multiplied by the number of bits in a word.*
- 2. *'Continuous throughput' is the fastest data rate the instrument can record to disk or solid-state drive memory without the loss of any information while sustaining the input digital data rate or digitizer conversion rate.*

- 7. Real-time oscilloscopes having all of the following:
 - a. A vertical root-mean-square (rms) noise voltage of less than 2% of full-scale at the vertical scale setting that provides the lowest noise value; and
 - b. An 'upper 3dB frequency' greater than 90 GHz on any channel.

Note: 3A002.a.7. does not control equivalent-time sampling oscilloscopes.

Technical Notes:

For the purposes of 3A002.a.7.b.:

- 1. *'Upper 3dB frequency' is the greater of:*
 - a. *The specified 3dB bandwidth of the oscilloscope; or*
 - b. *The maximum upper end of the frequency range of any 'movable bandwidth window'.*
- 2. *'Movable bandwidth window' is a bandpass filter with a user-definable centre frequency or span.*

3A002 continued

- b. Not used;
- c. "Signal analysers" as follows:
 - 1. "Signal analysers" having a 3 dB resolution bandwidth (RBW) exceeding 40 MHz anywhere within the frequency range exceeding 31,8 GHz but not exceeding 37 GHz;
 - 2. "Signal analysers" having a Displayed Average Noise Level (DANL) less (better) than -160 dBm/Hz anywhere within the frequency range exceeding 43,5 GHz but not exceeding 110 GHz;
 - 3. "Signal analysers" having a frequency exceeding 110 GHz;
 - 4. "Signal analysers" having all of the following:
 - a. 'Real-time bandwidth' exceeding 520 MHz; and
 - b. Having any of the following:
 - 1. 100% probability of discovery with less than a 3 dB reduction from full amplitude due to gaps or windowing effects of signals having a duration of 8 µs or less; or
 - 2. A 'frequency mask trigger' function with 100% probability of trigger (capture) for signals having a duration of 8 µs or less;

Technical Notes:

1. *For the purposes of 3A002.c.4.a., 'real-time bandwidth' is the widest frequency range for which the analyser can continuously transform time-domain data entirely into frequency-domain results, using a Fourier or other discrete time transform that processes every incoming time point, without a reduction of measured amplitude of more than 3 dB below the actual signal amplitude caused by gaps or windowing effects, while outputting or displaying the transformed data.*
2. *For the purposes of 3A002.c.4.b.1., probability of discovery is also referred to as probability of intercept or probability of capture.*
3. *For the purposes of 3A002.c.4.b.1., the duration for 100% probability of discovery is equivalent to the minimum signal duration necessary for the specified level measurement uncertainty.*
4. *For the purposes of 3A002.c.4.b.2., a 'frequency mask trigger' is a mechanism where the trigger function is able to select a frequency range to be triggered on as a subset of the acquisition bandwidth while ignoring other signals that may also be present within the same acquisition bandwidth. A 'frequency mask trigger' may contain more than one independent set of limits.*

Note: 3A002.c.4. does not control those "signal analysers" using only constant percentage bandwidth filters (also known as octave or fractional octave filters).

3A002.c. continued

5. Not used;
- d. Signal generators having any of the following:
 1. Specified to generate pulse-modulated signals having all of the following, anywhere within the frequency range exceeding 31,8 GHz but not exceeding 37 GHz:
 - a. 'Pulse duration' of less than 25 ns; and
 - b. On/off ratio equal to or exceeding 65 dB;

Technical Note:

For the purposes of 3A002.d.1.a, 'pulse duration' is defined as the time interval from the point on the leading edge that is 50% of the pulse amplitude to the point on the trailing edge that is 50% of the pulse amplitude.

2. An output power exceeding 100 mW (20 dBm) anywhere within the frequency range exceeding 43,5 GHz but not exceeding 110 GHz;
3. A "frequency switching time" as specified in any of the following:
 - a. Not used;
 - b. Less than 100 μ s for any frequency change exceeding 2,2 GHz within the frequency range exceeding 4,8 GHz but not exceeding 31,8 GHz;
 - c. Not used;
 - d. Less than 500 μ s for any frequency change exceeding 550 MHz within the frequency range exceeding 31,8 GHz but not exceeding 37 GHz;
 - e. Less than 100 μ s for any frequency change exceeding 2,2 GHz within the frequency range exceeding 37 GHz but not exceeding 75 GHz; or
 - f. Not used;
 - g. Less than 100 μ s for any frequency change exceeding 5,0 GHz within the frequency range exceeding 75 GHz but not exceeding 110 GHz;

3A002.d. continued

4. A Single Sideband (SSB) phase noise, in dBc/Hz, specified as being any of the following:
 - a. Less (better) than $-(126 + 20\log_{10}F - 20\log_{10}f)$ anywhere within the range of $10 \text{ Hz} \leq F \leq 10 \text{ kHz}$ anywhere within the frequency range exceeding 3,2 GHz but not exceeding 110 GHz; or
 - b. Less (better) than $-(206 - 20\log_{10}f)$ anywhere within the range of $10 \text{ kHz} < F \leq 100 \text{ kHz}$ anywhere within the frequency range exceeding 3,2 GHz but not exceeding 110 GHz;

Technical Note:

For the purposes of 3A002.d.4., F is the offset from the operating frequency in Hz and f is the operating frequency in MHz;

5. A 'Radio Frequency (RF) modulation bandwidth' of digital baseband signals as specified in any of the following:
 - a. Exceeding 2,2 GHz within the frequency range exceeding 4,8 GHz but not exceeding 31,8 GHz;
 - b. Exceeding 550 MHz within the frequency range exceeding 31,8 GHz but not exceeding 37 GHz;
 - c. Exceeding 2,2 GHz within the frequency range exceeding 37 GHz but not exceeding 75 GHz; or
 - d. Exceeding 5,0 GHz within the frequency range exceeding 75 GHz but not exceeding 110 GHz; or

Technical Note:

For the purposes of 3A002.d.5., 'RF modulation bandwidth' is the RF bandwidth occupied by a digitally encoded baseband signal modulated onto an RF signal. It is also referred to as information bandwidth or vector modulation bandwidth. I/Q digital modulation is the technical method for producing a vector-modulated RF output signal, and that output signal is typically specified as having an 'RF modulation bandwidth'.

3A002.d. continued

6. A maximum frequency exceeding 110 GHz;

Note 1: 3A002.d. includes arbitrary waveform and function generators.

Note 2: 3A002.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.

Technical Note:

For the purposes of 3A002.d., the maximum output frequency of an arbitrary waveform or function generator is calculated by dividing the sample rate, in samples/second, by a factor of 2,5.

3A002 continued

- e. Network analysers having any of the following:
 - 1. An output power exceeding 100 mW (20 dBm) anywhere within the operating frequency range exceeding 43,5 GHz but not exceeding 110 GHz;
 - 2. Not used;
 - 3. 'Nonlinear vector measurement functionality' at frequencies exceeding 50 GHz but not exceeding 110 GHz; or

Technical Note:

For the purposes of 3A002.e.3., 'nonlinear vector measurement functionality' is an instrument's ability to analyse the test results of devices driven into the large-signal domain or the non-linear distortion range.

- 4. A maximum operating frequency exceeding 110 GHz;
- f. Microwave test receivers having all of the following:
 - 1. A maximum operating frequency exceeding 110 GHz; and
 - 2. Being capable of measuring amplitude and phase simultaneously;
- g. Atomic frequency standards being any of the following:
 - 1. "Space-qualified";
 - 2. Non-rubidium and having a long-term stability less (better) than 1×10^{-11} /month; or
 - 3. Non-"space-qualified" and having all of the following:
 - a. Being a rubidium standard;
 - b. Long-term stability less (better) than 1×10^{-11} /month; and
 - c. Total power consumption of less than 1 W;

3A002 continued

- h. "Electronic assemblies", modules, or equipment, specified to perform all of the following:
 - 1. Analogue-to-digital conversions meeting any of the following:
 - a. Not used;
 - b. A resolution of 10 bit or more, but less than 12 bit, with a "sample rate" greater than 1,0 GSPS;
 - c. A resolution of 12 bit or more, but less than 14 bit, with a "sample rate" greater than 1,0 GSPS;
 - d. A resolution of 14 bit or more, but less than 16 bit, with a "sample rate" greater than 400 Mega Samples Per Second (MSPS); or
 - e. A resolution of 16 bit or more with a "sample rate" greater than 180 MSPS; and
 - 2. Any of the following:
 - a. Output of digitised data;
 - b. Storage of digitised data; or
 - c. Processing of digitised data.

N.B. *Digital data recorders, oscilloscopes, "signal analysers", signal generators, network analysers and microwave test receivers, are specified in 3A002.a.6., 3A002.a.7., 3A002.c., 3A002.d., 3A002.e. and 3A002.f., respectively.*

3A002.h. continued

Technical Notes:

For the purposes of 3A002.h.:

1. *A resolution of n bit corresponds to a quantisation of 2^n levels.*
2. *The resolution of the ADC is the number of bits of the digital output of the ADC that represents the measured analogue input. Effective Number of Bits (ENOB) is not used to determine the resolution of the ADC.*
3. *For non-interleaved multiple-channel "electronic assemblies", modules, or equipment, the "sample rate" is not aggregated and the "sample rate" is the maximum rate of any single-channel.*
4. *For interleaved channels on multiple-channel "electronic assemblies", modules, or equipment, the "sample rates" are aggregated and the "sample rate" is the maximum combined total rate of all the interleaved channels.*

Note: *3A002.h. includes ADC cards, waveform digitizers, data acquisition cards, signal acquisition boards and transient recorders.*

3A003 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.

3A101 Electronic equipment, devices and components, other than those specified in 3A001, as follows:

- a. Analogue-to-Digital Converters (ADCs), usable in "missiles", designed to meet military specifications for ruggedized equipment;
- b. Accelerators capable of delivering electromagnetic radiation produced by bremsstrahlung from accelerated electrons of 2 MeV or greater, and systems containing those accelerators.

Note: 3A101.b. does not specify equipment specially designed for medical purposes.

3A102 'Thermal batteries' designed or modified for 'missiles'.

Technical Notes:

1. *In 3A102 'thermal batteries' are single use batteries that contain a solid non-conducting inorganic salt as the electrolyte. These batteries incorporate a pyrolytic material that, when ignited, melts the electrolyte and activates the battery.*
2. *In 3A102 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.*

3A201 Electronic components, other than those specified in 3A001, as follows;

- a. Capacitors having either of the following sets of characteristics:
 1.
 - a. Voltage rating greater than 1,4 kV;
 - b. Energy storage greater than 10 J;
 - c. Capacitance greater than 0,5 μ F; and
 - d. Series inductance less than 50 nH; or
 2.
 - a. Voltage rating greater than 750 V;
 - b. Capacitance greater than 0,25 μ F; and
 - c. Series inductance less than 10 nH;

3A201 continued

- b. Superconducting solenoidal electromagnets having all of the following characteristics:
 - 1. Capable of creating magnetic fields greater than 2 T;
 - 2. A ratio of length to inner diameter greater than 2;
 - 3. Inner diameter greater than 300 mm; and
 - 4. Magnetic field uniform to better than 1% over the central 50% of the inner volume;

Note: 3A201.b. does not control magnets specially designed for and exported 'as parts of' medical nuclear magnetic resonance (NMR) imaging systems. The phrase 'as part of' does not necessarily mean physical part in the same shipment; separate shipments from different sources are allowed, provided the related export documents clearly specify that the shipments are dispatched 'as part of' the imaging systems.

- c. Flash X-ray generators or pulsed electron accelerators having either of the following sets of characteristics:
 - 1.
 - a. An accelerator peak electron energy of 500 keV or greater but less than 25 MeV; and
 - b. With a 'figure of merit' (K) of 0,25 or greater; or
 - 2.
 - a. An accelerator peak electron energy of 25 MeV or greater; and
 - b. A 'peak power' greater than 50 MW.

Note: 3A201.c. does not control accelerators that are component parts of devices designed for purposes other than electron beam or X-ray radiation (electron microscopy, for example) nor those designed for medical purposes.

Technical Notes:

1. The 'figure of merit' (K) is defined as:

$$K = 1,7 \times 10^3 V^{2,65} Q$$

V is the peak electron energy in million electron volts.
 If the accelerator beam pulse duration is less than or equal to 1 μ s, then *Q* is the total accelerated charge in Coulombs. If the accelerator beam pulse duration is greater than 1 μ s, then *Q* is the maximum accelerated charge in 1 μ s.
Q equals the integral of *i* with respect to *t*, over the lesser of 1 μ s or the time duration of the beam pulse ($Q = \int i dt$), where *i* is beam current in amperes and *t* is time in seconds.
2. 'Peak power' = (peak potential in volts) x (peak beam current in amperes).
3. In machines based on microwave accelerating cavities, the time duration of the beam pulse is the lesser of 1 μ s or the duration of the bunched beam packet resulting from one microwave modulator pulse.
4. In machines based on microwave accelerating cavities, the peak beam current is the average current in the time duration of a bunched beam packet.

3A225 Frequency changers or generators, other than those specified in 0B001.b.13., usable as a variable or fixed frequency motor drive, having all of the following characteristics:

- N.B.1. "Software" specially designed to enhance or release the performance of a frequency changer or generator to meet the characteristics of 3A225 is specified in 3D225.
- N.B.2. "Technology" in the form of codes or keys to enhance or release the performance of a frequency changer or generator to meet the characteristics of 3A225 is specified in 3E225.

3A225 continued

- a. Multiphase output providing a power of 40 VA or greater;
- b. Operating at a frequency of 600 Hz or more; and
- c. Frequency control better (less) than 0,2%.

Note: 3A225 does not control frequency changers or generators if they have hardware, "software" or "technology" constraints that limit the performance to less than that specified above, provided they meet any of the following:

- 1. They need to be returned to the original manufacturer to make the enhancements or release the constraints;
- 2. They require "software" as specified in 3D225 to enhance or release the performance to meet the characteristics of 3A225; or
- 3. They require "technology" in the form of keys or codes as specified in 3E225 to enhance or release the performance to meet the characteristics of 3A225.

Technical Notes:

- 1. Frequency changers in 3A225 are also known as converters or inverters.
- 2. Frequency changers in 3A225 may be marketed as Generators, Electronic Test Equipment, AC Power Supplies, Variable Speed Motors Drives, Variable Speed Drives (VSDs), Variable Frequency Drives (VFDs), Adjustable Frequency Drives (AFDs), or Adjustable Speed Drives (ASDs).

3A226 High-power direct current power supplies, other than those specified in 0B001.j.6., having both of the following characteristics:

- a. Capable of continuously producing, over a time period of 8 hours, 100 V or greater with current output of 500 A or greater; and
- b. Current or voltage stability better than 0,1% over a time period of 8 hours.

3A227 High-voltage direct current power supplies, other than those specified in 0B001.j.5., having both of the following characteristics:

- a. Capable of continuously producing, over a time period of 8 hours, 20 kV or greater with current output of 1 A or greater; and
- b. Current or voltage stability better than 0,1% over a time period of 8 hours.

3A228 Switching devices, as follows:

- a. Cold-cathode tubes, whether gas filled or not, operating similarly to a spark gap, having all of the following characteristics:
 1. Containing three or more electrodes;
 2. Anode peak voltage rating of 2,5 kV or more;
 3. Anode peak current rating of 100 A or more; and
 4. Anode delay time of 10 μ s or less;

Note: 3A228.a. includes gas krytron tubes and vacuum sprytron tubes.

- b. Triggered spark-gaps having both of the following characteristics:
 1. An anode delay time of 15 μ s or less; and
 2. Rated for a peak current of 500 A or more;
- c. Modules or assemblies with a fast switching function, other than those specified in 3A001.g. or 3A001.h., having all of the following characteristics:
 1. Anode peak voltage rating greater than 2 kV;
 2. Anode peak current rating of 500 A or more; and
 3. Turn-on time of 1 μ s or less.

3A229 High-current pulse generators as follows:

N.B. SEE ALSO MILITARY GOODS CONTROLS.

- a. Detonator firing sets (initiator systems, firesets), including electronically-charged, explosively-driven and optically-driven firing sets, other than those specified in 1A007.a., designed to drive multiple controlled detonators specified in 1A007.b.;
- b. Modular electrical pulse generators (pulsers) having all of the following characteristics:
 - 1. Designed for portable, mobile, or ruggedized-use;
 - 2. Capable of delivering their energy in less than 15 μ s into loads of less than 40 ohms;
 - 3. Having an output greater than 100 A;
 - 4. No dimension greater than 30 cm;
 - 5. Weight less than 30 kg; and
 - 6. Specified for use over an extended temperature range 223 K (-50°C) to 373 K (100°C) or specified as suitable for aerospace applications.

Note: 3A229.b. includes xenon flash-lamp drivers.

- c. Micro-firing units having all of the following characteristics:
 - 1. No dimension greater than 35 mm;
 - 2. Voltage rating of equal to or greater than 1 kV; and
 - 3. Capacitance of equal to or greater than 100 nF.

3A230 High-speed pulse generators, and 'pulse heads' therefor, having both of the following characteristics:

- a. Output voltage greater than 6 V into a resistive load of less than 55 ohms; and
- b. 'Pulse transition time' less than 500 ps.

Technical Notes:

- 1. In 3A230, 'pulse transition time' is defined as the time interval between 10% and 90% voltage amplitude.
- 2. 'Pulse heads' are impulse forming networks designed to accept a voltage step function and shape it into a variety of pulse forms that can include rectangular, triangular, step, impulse, exponential, or monocycle types. 'Pulse heads' can be an integral part of the pulse generator, they can be a plug-in module to the device or they can be an externally connected device.

3A231 Neutron generator systems, including tubes, having both of the following characteristics:

- a. Designed for operation without an external vacuum system; and
- b. Utilising any of the following:
 - 1. Electrostatic acceleration to induce a tritium-deuterium nuclear reaction;
or
 - 2. Electrostatic acceleration to induce a deuterium-deuterium nuclear reaction and capable of an output of 3×10^9 neutrons/s or greater.

3A232 Multipoint initiation systems, other than those specified in 1A007, as follows:

N.B. SEE ALSO MILITARY GOODS CONTROLS.

N.B. See 1A007.b. for detonators.

- a. Not used;
- b. Arrangements using single or multiple detonators designed to nearly simultaneously initiate an explosive surface over an area greater than 5 000 mm² from a single firing signal with an initiation timing spread over the surface of less than 2,5 µs.

Note: 3A232 does not control detonators using only primary explosives, such as lead azide.

3A233 Mass spectrometers, other than those specified in 0B002.g., capable of measuring ions of 230 u or greater and having a resolution of better than 2 parts in 230, as follows, and ion sources therefor:

- a. Inductively coupled plasma mass spectrometers (ICP/MS);
- b. Glow discharge mass spectrometers (GDMS);
- c. Thermal ionisation mass spectrometers (TIMS);
- d. Electron bombardment mass spectrometers having both of the following features:
 1. A molecular beam inlet system that injects a collimated beam of analyte molecules into a region of the ion source where the molecules are ionised by an electron beam; and
 2. One or more 'cold traps' that can be cooled to a temperature of 193 K (-80°C);
- e. Not used;
- f. Mass spectrometers equipped with a microfluorination ion source designed for actinides or actinide fluorides.

Technical Notes:

1. *Electron bombardment mass spectrometers in 3A233.d. are also known as electron impact mass spectrometers or electron ionisation mass spectrometers.*
2. *In 3A233.d.2., a 'cold trap' is a device that traps gas molecules by condensing or freezing them on cold surfaces. For the purposes of 3A233.d.2., a closed-loop gaseous helium cryogenic vacuum pump is not a 'cold trap'.*

3A234 Striplines to provide low inductance path to detonators with the following characteristics:

- a. Voltage rating greater than 2 kV; and
- b. Inductance of less than 20 nH.

3A501 Electronic items as follows:

- a. General purpose integrated circuits, as follows:
 15. Complementary Metal Oxide Semiconductor (CMOS) integrated circuits, not specified in 3A001.a.2., designed to operate at an ambient temperature equal to or less (better) than 4,5 K (-268,65°C).

Technical Note:

For the purposes of 3A501.a.15., CMOS integrated circuits are also referred to as cryogenic CMOS or cryoCMOS integrated circuits.

16. Integrated circuits, having one or more digital processing units, having any of the following:
 - a. A 'Total Processing Performance' ('TPP') greater than or equal to 6 000; or
 - b. A 'TPP' greater than or equal to 1 600 and less than 6 000 and a 'performance density' greater than or equal to 5,92;

Note: 3A501.a.16.b. does not control items that are not designed for use in 'data centres'.

N.B. For computers, "electronic assemblies" and components containing integrated circuits specified in 3A501.a.16., see 4A507.

Technical Notes:

For the purposes of 3A501.a.16.:

1. *'Total Processing Performance' ('TPP') is $2 \times \text{'MacTOPS'} \times \text{'bit length of the operation'}$, aggregated over all processing units on the integrated circuit.*
 - a. *'MacTOPS' is the theoretical peak number of Tera (10^{12}) operations per second for multiply-accumulate computation ($D=A \times B + C$).*
 - b. *The 2 in the 'TPP' formula is based on industry convention of counting one multiply-accumulate computation, $D=A \times B + C$, as 2 operations for the purpose of datasheets. Therefore, $2 \times \text{MacTOPS}$ may correspond to the reported TOPS or FLOPS on a datasheet.*
 - c. *'Bit length of the operation' for a multiply-accumulate computation is the largest bit-length of the inputs to the multiply operation.*
 - d. *Aggregate the 'TPPs' for each processing unit on the integrated circuit to arrive at a total. $\text{'TPP'} = \text{TPP1} + \text{TPP2} + \dots + \text{TPPn}$ (where n is the number of processing units on the integrated circuit).*
2. *The rate of 'MacTOPS' is to be calculated at its maximum value theoretically possible. The rate of 'MacTOPS' is assumed to be the highest value the manufacturer claims in a manual or brochure for the integrated circuit. For example, the 'TPP' threshold of 6 000 can be met with 750 tera integer operations (or 2×375 'MacTOPS') at 8 bits or 375 tera FLOPS at 16 bits. If the IC is designed for MAC computation with multiple bit lengths that achieve different 'TPP' values, the highest 'TPP' value should be evaluated against parameters in 3A501.a.16.*
3. *For integrated circuits, specified in 3A501.a.16., that provide processing of both sparse and dense matrices, the 'TPP' values are the values for processing of dense matrices (e.g., without sparsity).*
4. *'Performance density' is 'TPP' divided by 'applicable die area'. 'Applicable die area' is measured in millimetres squared and includes all die area of logic dies manufactured with a process node that uses a non-planar transistor architecture.*
5. *'Data centre' is a structure, or group of structures, dedicated to the centralised accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage, processing or transmission services together with all the facilities and infrastructure for power distribution and environmental control.*

- b. Microwave or millimetre wave items as follows:

13. Parametric signal amplifiers having all of the following:
 - a. Designed for operation at an ambient temperature below 1 K (-272,15°C);
 - b. Designed for operation at any frequency from 2 GHz up to and including 15 GHz; and
 - c. A noise figure less (better) than 0,015 dB at any frequency from 2 GHz up to and including 15 GHz at 1 K (-272,15°C).

Note: Parametric signal amplifiers include Travelling Wave Parametric Amplifiers (TWPAs).

Technical Note:

For the purposes of 3A501.b.13., parametric signal amplifiers may also be referred to as Quantum-Limited Amplifiers (QLAs).

- f. Rotary input type absolute position inductive encoders, not specified in 3A001.f., having all of the following:
 1. Digital output;
 2. Outer diameter less than or equal to 40 mm; and
 3. Resolution equal to or greater than 16 bits;
- h. Solid-state power semiconductor switches, diodes, or 'modules', rated for a maximum operating junction temperature less than or equal to 488 K (215°C) and having all of the following:
 1. Repetitive peak off-state voltage (blocking voltage) exceeding 5000 V;
 2. Continuous current greater than 1 A; and
 3. Semiconductor material with a bandgap of more than 2.0 eV.

Note 1: Repetitive peak off-state voltage in 3A501.h. includes drain to source voltage, collector to emitter voltage, repetitive peak reverse voltage and peak repetitive off-state blocking voltage.

Note 2: 3A501.h. includes:

- Junction Field Effect Transistors (JFETs)
- Vertical Junction Field Effect Transistors (VJFETs)
- Metal Oxide Semiconductor Field Effect Transistors (MOSFETs)
- Double Diffused Metal Oxide Semiconductor Field Effect Transistor (DMOSFET)
- Insulated Gate Bipolar Transistor (IGBT)
- High Electron Mobility Transistors (HEMTs)
- Bipolar Junction Transistors (BJTs)
- Thyristors and Silicon Controlled Rectifiers (SCRs)
- Gate Turn-Off Thyristors (GTOs)
- Emitter Turn-Off Thyristors (ETOs)

- PiN Diodes
- Schottky Diodes

Note 3: 3A501.h. does not apply to switches, diodes, or 'modules', incorporated into equipment designed for civil automobile, civil railway, "civil aircraft", civil power transmission and distribution, or civil 'energy conversion' applications.

Note 4: 3A501.h. includes silicon carbide, gallium nitride, and gallium oxide semiconductor switches, diodes or 'modules'.

Technical Notes:

For the purposes of 3A501.h.:

1. 'Modules' contain one or more solid-state power semiconductor switches or diodes.
2. 'Energy conversion' is the process of converting one form of energy into another form of energy.

N.B. SEE ALSO 3A001.h.

3A502 General purpose "electronic assemblies", modules and equipment, as follows:

- i. "Electronic assemblies", modules or equipment, containing one or more 'user configurable' Field Programmable Logic Devices (FPLDs) and having an 'aggregate lookup table input count' of greater than or equal to 1 800 000.

N.B. For items having FPLDs that are combined with an Analogue-to-Digital Converter (ADC), rated for extended operating temperatures or are radiation hardened, or have cryptographic functionality, see 3A002.h., 4A001.a., and 5A002.a. respectively.

Technical Notes:

For the purposes of 3A502.i.:

1. 'User configurable' means a user can configure or modify the logic cells or interconnects between logic cells within the FPLD logic fabric to prescribe the specific function that the 3A502.i. item performs.
2. 'Aggregate lookup table input count' is the sum of the number of independent inputs available to each programmable Lookup Table (LUT), as accumulated across all physical LUTs contained within a FPLD or other programmable item. An example is: a circuit board containing 2 FPGAs, each having 150 000 programmable LUTs with 6 inputs, would have an 'aggregate lookup table input count' of $2 \times 150\,000 \times 6 = 1\,800\,000$.

3A504 Cryogenic cooling systems and components, as follows:

- a. Systems rated to provide a cooling power greater than or equal to 600 μ W at or below a temperature of 0,1 K (-273,05°C) for a period of greater than 48 hours;
- b. Two-stage pulse tube cryocoolers rated to maintain a temperature below 4 K (-269,15°C) and provide a cooling power greater than or equal to 1,5 W at or below a temperature of 4,2 K (-268,95°C).

3B Test, Inspection and Production Equipment

3B001 Equipment for the manufacturing of semiconductor devices or materials, as follows and specially designed components and accessories therefor:

N.B. SEE ALSO 2B226

a. Equipment designed for epitaxial growth as follows:

1. Equipment designed or modified to produce a layer of any material other than silicon with a thickness uniform to less than $\pm 2,5\%$ across a distance of 75 mm or more;

Note: 3B001.a.1. includes Atomic Layer Epitaxy (ALE) equipment.

2. Metal Organic Chemical Vapour Deposition (MOCVD) reactors designed for compound semiconductor epitaxial growth of material having two or more of the following elements: aluminium, gallium, indium, arsenic, phosphorus, antimony, oxygen or nitrogen;
3. Molecular beam epitaxial growth equipment using gas or solid sources;

N.B. For equipment designed for epitaxial growth of silicon (Si) or silicon germanium (SiGe), see 3B501.a.4.

b. Equipment designed for ion implantation and having any of the following:

1. Not used;
2. Being designed and optimised to operate at a beam energy of 20 keV or more and a beam current of 10 mA or more for hydrogen, deuterium or helium implant;
3. Direct write capability;
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"; or
5. Being designed and optimised to operate at a beam energy of 20 keV or more and a beam current of 10 mA or more for silicon implant into a semiconductor material "substrate" heated to 600°C or greater;

3B001 continued

- c. Not used;
- d. Not used;
- 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 functionally different 'semiconductor process tools' specified in 3B001.a.1., 3B001.a.2., 3B001.a.3. or 3B001.b. are designed to be connected; and
 - 2. Designed to form an integrated system in a vacuum environment for 'sequential multiple wafer processing';

Note: 3B001.e. does not control automatic robotic wafer handling systems specially designed for parallel wafer processing.

Technical Notes:

- 1. For the purposes of 3B001.e.1., 'semiconductor process tools' refers to modular tools that provide physical processes for semiconductor "production" that are functionally different, such as deposition, implant or thermal processing.
- 2. For the purposes of 3B001.e.2., 'sequential multiple wafer processing' means the capability to process each wafer in different 'semiconductor process tools', such as by transferring each wafer from one tool to a second tool and on to a third tool with the automatic loading multi-chamber central wafer handling systems.

3B001 continued

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 and having any of the following:

- a. A light source wavelength shorter than 193 nm; or
- b. Capable of producing a pattern with a 'Minimum Resolvable Feature size' ('MRF') of 45 nm or less;

Technical Note:

For the purposes of 3B001.f.1.b., the 'Minimum Resolvable Feature size' ('MRF') is calculated by the following formula:

$$'MRF' = \frac{(an\ exposure\ light\ source\ wavelength\ in\ nm) \times (K\ factor)}{maximum\ numerical\ aperture}$$

where, the K factor = 0,35.

N.B. SEE ALSO 3B501.f.

2. Imprint lithography equipment capable of producing features of 45 nm or less;

Note: 3B001.f.2. includes:

- Micro contact printing tools;
- Hot embossing tools;
- Nano-imprint lithography tools;
- Step and Flash Imprint Lithography (S-FIL) tools.

3. Equipment specially designed for mask making having all of the following:

- a. A deflected focussed electron beam, ion beam or "laser" beam; and
- b. Having any of the following:
 1. A Full-Width Half-Maximum (FWHM) spot size smaller than 65 nm and an image placement less than 17 nm (mean + 3 sigma); or
 2. Not used;
 3. A second-layer overlay error of less than 23 nm (mean + 3 sigma) on the mask;

3B001.f. continued

4. Equipment designed for device processing using direct writing methods, having all of the following:
 - a. A deflected focused electron beam; and
 - b. Having any of the following:
 1. A minimum beam size equal to or smaller than 15 nm; or
 2. An overlay error less than 27 nm (mean + 3 sigma);
- g. Masks and reticles, designed for integrated circuits specified in 3A001, 3A501.a.15. or 3A501.a.16.;
- h. Multi-layer masks with a phase shift layer not specified in 3B001.g. and designed to be used by lithography equipment having a light source wavelength less than 245 nm;
Note: 3B001.h. does not control multi-layer masks with a phase shift layer designed for the fabrication of memory devices not specified in 3A001.
N.B. For masks and reticles, specially designed for optical sensors, see 6B002.
- i. Imprint lithography templates designed for integrated circuits specified in 3A001, 3A501.a.15. or 3A501.a.16.;
- j. Mask "substrate blanks" with multilayer reflector structure consisting of molybdenum and silicon, and having all of the following:
 1. Specially designed for "Extreme Ultraviolet" ("EUV") lithography; and
 2. Compliant with SEMI Standard P37.

3B002 Test equipment specially designed for testing finished or unfinished semiconductor devices as follows and specially designed components and accessories therefor:

- a. For testing S-parameters of items specified in 3A001.b.3.;
- b. Not used;
- c. For testing items specified in 3A001.b.2.

3B501 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:
 4. Equipment designed for epitaxial growth of silicon (Si) or silicon germanium (SiGe), and having all of the following:
 - a. At least one preclean chamber designed to provide a surface preparation means to clean the surface of the wafer; and
 - b. An epitaxial deposition chamber designed to operate at a temperature below 958 K (685°C).

Note: 3B501.a.4. includes Atomic Layer Epitaxy (ALE) equipment.

- 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 and having any of the following:
 - a. Not used;
 - b. Having all of the following:
 1. A light source wavelength equal to or longer than 193 nm;
 2. Capable of producing a pattern with a 'Minimum Resolvable Feature size' ('MRF') of 45 nm or less; and
 3. A maximum 'dedicated chuck overlay' value of less than or equal to 1,50 nm;

Technical Notes:

For the purposes of 3B501.f.1.b.:

1. *The 'Minimum Resolvable Feature size' ('MRF') is calculated by the following formula:*

$$'MRF' = \frac{(an\ exposure\ light\ source\ wavelength\ in\ nm) \times (K\ factor)}{maximum\ numerical\ aperture}$$

where, the K factor = 0,25.

'MRF' is also known as resolution.

2. *'Dedicated chuck overlay' is the alignment accuracy of a new pattern to an existing pattern printed on a wafer by the same lithographic system. 'Dedicated chuck overlay' is also known as single machine overlay.*

N.B. SEE ALSO 3B001.f.1.

- k. Equipment designed for dry etching having any of the following:
1. Equipment designed or modified for isotropic dry etching, having a largest 'silicon germanium-to-silicon (SiGe:Si) etch selectivity' of greater than or equal to 100:1; or
 2. Equipment designed or modified for anisotropic dry etching, having all of the following:
 - a. Radio Frequency (RF) power source(s) with at least one pulsed RF output;
 - b. One or more fast gas switching valve(s) with switching time less than 300 milliseconds; and
 - c. Electrostatic chuck with twenty or more individually controllable variable temperature elements;

Note 1: *3B501.k. includes etching by 'radicals', ions, sequential reactions, or non-sequential reaction.*

Note 2: *3B501.k.2. includes etching using RF pulse excited plasma, pulsed duty cycle excited plasma, pulsed voltage on electrodes modified plasma, cyclic injection and purging of gases combined with a*

plasma, plasma atomic layer etching, or plasma quasi-atomic layer etching.

Technical Notes:

For the purposes of 3B501.k.:

1. 'Silicon germanium-to-silicon (SiGe:Si) etch selectivity' is measured for a germanium concentration of greater than or equal to 30% ($\text{Si}_{0,70} \text{Ge}_{0,30}$).
 2. 'Radical' is defined as an atom, molecule, or ion that has an unpaired electron in an open electron shell configuration.
1. "Extreme Ultraviolet" ("EUV") masks and "EUV" reticles, designed for integrated circuits, not specified in 3B001.g., and having a mask "substrate blank" specified in 3B001.j.;

Technical Note:

For the purposes of 3B501.l., masks or reticles with a mounted pellicle are considered masks and reticles.

- m. 'Pellicles' specially designed for "EUV" lithography.

Technical Note:

For the purposes of 3B501.m., a 'pellicle' is a membrane integrated with a frame, designed to protect a mask or reticle from particle contamination.

- n. Semiconductor manufacturing deposition equipment as follows:
 1. Atomic Layer Deposition (ALD) equipment as follows:
 - a. Equipment designed for the deposition of tungsten to fill an entire interconnect or in a channel less than 40 nm wide;
 - b. Equipment designed for 'area selective deposition' of a metal or metal nitride sidewall barrier using an organometallic compound precursor;

Technical Note:

For the purposes of 3B501.n.1.b., 'area selective deposition' refers to the deposition of material on the sidewall but not the bottom of a feature.

- c. Equipment designed for the deposition of a 'work function metal' composed of titanium aluminium carbide (TiAlC) and having a work function greater than 4,0 eV, and having all of the following:
 1. More than one metal source of which one is functioning as an aluminium precursor source; and
 2. A precursor vessel designed to operate at a temperature greater than or equal to 303,15 K (30°C);

Technical Note:

For the purposes of 3B501.n.1.c., 'work function metal' is a material that controls the threshold voltage of a transistor.

- d. Equipment designed or modified for deposition of molybdenum, ruthenium, or combinations thereof, having all of the following:
 1. Designed to operate with a metal precursor source designed or modified to operate at a temperature greater than 348 K (75°C); and

2. A process chamber (module) using a reducing agent containing hydrogen at a pressure equal to or greater than 4 kPa;

Technical Note:

For the purposes of 3B501.n.1.d.1., the metal precursor source need not be integrated with the equipment. The metal precursor could be delivered by an on-tool source or sub-fab metal precursor source.

2. Equipment designed for cobalt electroplating or cobalt electroless-plating deposition processes;
3. Equipment designed for Chemical Vapour Deposition (CVD) of cobalt fill metal;
4. Equipment designed for 'selective bottom-up' Chemical Vapour Deposition (CVD) of tungsten fill metal;

Technical Note:

For the purposes of 3B501.n.4., 'selective bottom-up' refers to the preferential deposition of material on the bottom relative to the sidewall.

5. Equipment designed for void-free plasma enhanced deposition of a layer with a dielectric constant less than 3,3, in 'gaps' having an 'aspect ratio' equal to or greater than 1:1 and a width less than 25 nm;

Technical Notes:

For the purposes of 3B501.n.5.:

1. *A 'gap' is the space between metal lines.*
 2. *The 'aspect ratio' (depth : width) is defined as the ratio of the depth to the width of the gap between the metal lines.*
6. Equipment designed for the deposition of a ruthenium layer using an organometallic compound precursor, while maintaining the wafer substrate at a temperature greater than 293,15 K (20°C) and less than 773,15 K (500°C);
 7. Equipment designed for multistep processing in multiple chambers and maintaining high vacuum or inert environment during transfer between process steps, as follows:
 - a. Equipment designed to fabricate a metal contact by performing all of the following processes:
 1. Surface treatment plasma process using hydrogen, hydrogen and nitrogen, or ammonia (NH₃), while maintaining the wafer substrate at a temperature greater than 373,15 K (100°C) and less than 773,15 K (500°C);
 2. Surface treatment plasma process using oxygen or ozone, while maintaining the wafer substrate at a temperature greater than 313,15 K (40°C) and less than 773,15 K (500°C); and
 3. Deposition of a tungsten layer while maintaining the wafer substrate at a temperature greater than 373,15 K (100°C) and less than 773,15 K (500°C);

- b. Equipment designed to fabricate a metal contact by performing all of the following processes:
 - 1. Surface treatment plasma process using a remote plasma generator and an ion filter; and
 - 2. Deposition of a cobalt layer selectively onto copper using an organometallic compound precursor;
- c. Equipment designed to fabricate a metal contact by performing all of the following processes:
 - 1. Deposition of a titanium nitride (TiN) or tungsten carbide (WC) layer, using an organometallic compound precursor, while maintaining the wafer substrate at a temperature greater than 293,15 K (20°C) and less than 773,15 K (500°C);
 - 2. Deposition of a cobalt layer using a physical sputter deposition technique and having a process pressure greater than $1,33 \times 10^{-1}$ Pa (1 mTorr) and less than $1,33 \times 10^1$ Pa (100 mTorr), while maintaining the wafer substrate at a temperature less than 773,15 K (500°C); and
 - 3. Deposition of a cobalt layer using an organometallic compound precursor and having a process pressure greater than $1,33 \times 10^2$ Pa (1 Torr) and less than $1,33 \times 10^4$ Pa (100 Torr), while maintaining the wafer substrate at a temperature greater than 293,15 K (20°C) and less than 773,15 K (500°C);
- d. Equipment designed to fabricate copper interconnects by performing all of the following processes:
 - 1. Deposition of a cobalt or ruthenium layer using an organometallic compound precursor and having a process pressure greater than $1,33 \times 10^2$ Pa (1 Torr) and less than $1,33 \times 10^4$ Pa (100 Torr), while maintaining the wafer substrate at a temperature greater than 293,15 K (20°C) and less than 773,15 K (500°C); and
 - 2. Deposition of a copper layer using a Physical Vapour Deposition (PVD) technique having a process pressure greater than $1,33 \times 10^{-1}$ Pa (1 mTorr) and less than $1,33 \times 10^1$ Pa (100 mTorr), while maintaining the wafer substrate at a temperature less than 773,15 K (500°C);
- 8. Equipment designed to fabricate a metal contact by multistep processing within a single chamber by performing all of the following:
 - a. Deposition of a tungsten layer, using an organometallic compound precursor, while maintaining the wafer substrate at a temperature greater than 373,15 K (100°C) and less than 773,15 K (500°C); and
 - b. Surface treatment plasma process using hydrogen, hydrogen and nitrogen, or ammonia (NH₃);
- o. Equipment designed for coating, depositing, baking, or developing photoresist formulated for "EUV" lithography;

- p. Inspection equipment designed for the detection of defects in, or particles on, "EUV" mask blanks or "EUV" patterned masks;
- q. Single wafer wet cleaning equipment with 'surface modification' drying;
Technical Note:
For the purposes of 3B501.q., 'surface modification' refers to silylation of a surface.
- r. Equipment designed for single wafer cleaning using supercritical CO₂ or sublimation drying;
- s. Equipment designed for "EUV" 'pattern shaping';
Technical Note:
For the purposes of 3B501.s., 'pattern shaping' is a deposition or removal process used to improve overall patterning by reshaping or trimming patterns produced using "EUV" lithography. This process utilises non-vertical directed particles including ions, neutral particles, clusters, radicals, or light.
- t. Equipment designed for ion beam deposition or Physical Vapor Deposition (PVD) of a multi-layer reflector for "EUV" masks.

3B503 Scanning Electron Microscope (SEM) equipment designed for imaging semiconductor devices or integrated circuits, having all of the following:

- a. Stage placement accuracy less (better) than 30 nm;
- b. Stage positioning measurement performed using laser interferometry;
- c. Position calibration within a Field of View (FOV) based on laser interferometer length-scale measurement;
- d. Collects and stores images having more than 2×10^8 pixels;
- e. FOV overlap of less than 5% in vertical and horizontal directions;
- f. Stitching overlap of FOV less than 50 nm; and
- g. Accelerating voltage more than 21 kV.

Note 1: 3B503 includes SEM equipment designed for chip design recovery.

Note 2: 3B503 does not apply to SEM equipment designed to accept a Semiconductor Equipment and Materials International (SEMI) standard wafer carrier, such as a 200 mm or larger Front Opening Unified Pod (FOUP).

3B504 Cryogenic wafer probing equipment, having all of the following:

- a. Designed to test devices at temperatures less than or equal to 4,5 K (-268,65°C); and
- b. Designed to accommodate wafer diameters greater than or equal to 100 mm.

3C Materials

3C001 Hetero-epitaxial materials, not specified in 3C507, consisting of a "substrate" having stacked epitaxially grown multiple layers of any of the following:

- a. Silicon (Si);
- b. Germanium (Ge);
- c. Silicon carbide (SiC);
- d. "III/V compounds" of gallium or indium;
- e. Gallium Oxide (Ga₂O₃); or
- f. Diamond.

Note: 3C001.d. does not control a "substrate" having one or more P-type epitaxial layers of GaN, InGaN, AlGaN, InAlN, InAlGaN, GaP, GaAs, AlGaAs, InP, InGaP, AlInP or InGaAlP, independent of the sequence of the elements, except if the P-type epitaxial layer is between N-type layers.

3C002 Resist materials as follows and "substrates" coated with the following resists:

- a. Resists designed for semiconductor lithography as follows:
 1. Positive resists adjusted (optimised) for use at wavelengths less than 193 nm but equal to or greater than 15 nm;
 2. Resists adjusted (optimised) for use at wavelengths less than 15 nm but greater than 1 nm;
- b. All resists designed for use with electron beams or ion beams, with a sensitivity of 0,01 µcoulomb/mm² or better;
- c. Not used;
- d. All resists optimised for surface imaging technologies;
- e. All resists designed or optimised for use with imprint lithography equipment specified in 3B001.f.2. that use either a thermal or photo-curable process.

- 3C003 Organo-inorganic compounds as follows:
- a. Organo-metallic compounds of aluminium, gallium or indium, having all of the following:
 1. A purity (metal basis) greater (better) than 99,999%; and
 2. Aluminium, gallium or indium elements directly linked to carbon in the organic part of the molecule;
 - b. Organo-arsenic, organo-antimony and organo-phosphorus compounds, having all of the following:
 1. A purity (inorganic element basis) greater (better) than 99,999%; and
 2. Arsenic, antimony or phosphorus elements directly linked to carbon in the organic part of the molecule.
- 3C004 Hydrides of phosphorus, arsenic or antimony, having a purity greater (better) than 99,999%, even diluted in inert gases or hydrogen.
- Note: 3C004 does not control hydrides containing 20% molar or more of inert gases or hydrogen.*
- 3C005 High resistivity materials as follows:
- a. Silicon carbide (SiC), gallium nitride (GaN), aluminium nitride (AlN), aluminium gallium nitride (AlGaN), gallium oxide (Ga₂O₃) or diamond semiconductor "substrates", or ingots, boules, or other preforms of those materials, having resistivities greater than 10 000 ohm-cm at 20°C;
 - b. Polycrystalline "substrates" or polycrystalline ceramic "substrates", having resistivities greater than 10 000 ohm-cm at 20°C and having at least one non-epitaxial single-crystal layer of silicon (Si), silicon carbide (SiC), gallium nitride (GaN), aluminium nitride (AlN), aluminium gallium nitride (AlGaN), gallium oxide (Ga₂O₃) or diamond on the surface of the "substrate".
- N.B. For materials consisting of a "substrate" specified in 3C005 with at least one epitaxial layer, see 3C001 or 3C006.*
- 3C006 Materials, not specified in 3C001, consisting of a "substrate" specified in 3C005 with at least one epitaxial layer of silicon carbide (SiC), gallium nitride (GaN), aluminium nitride (AlN), aluminium gallium nitride (AlGaN), gallium oxide (Ga₂O₃) or diamond.
- 3C507 Epitaxial materials consisting of a "substrate" having at least one epitaxially grown layer of any of the following:
- a. Silicon having an isotopic impurity less than 0,08% of silicon isotopes other than silicon-28 or silicon-30; or
 - b. Germanium having an isotopic impurity less than 0,08% of germanium isotopes other than germanium-70, germanium-72, germanium-74, or germanium-76.
- 3C508 Fluorides, hydrides, or chlorides, of silicon or germanium, containing any of the following:
- a. Silicon having an isotopic impurity less than 0,08% of silicon isotopes other than silicon-28 or silicon-30; or

- b. Germanium having an isotopic impurity less than 0,08% of germanium isotopes other than germanium-70, germanium-72, germanium-74, or germanium-76.

3C509 Silicon, silicon oxides, germanium or germanium oxides, containing any of the following:

- a. Silicon having an isotopic impurity less than 0,08% of silicon isotopes other than silicon-28 or silicon-30; or
- b. Germanium having an isotopic impurity less than 0,08% of germanium isotopes other than germanium-70, germanium-72, germanium-74, or germanium-76.

Note: 3C509 includes "substrates", lumps, ingots, boules and preforms.

3D Software

- 3D001 "Software" specially designed for the "development" or "production" of equipment specified in 3A001.b. to 3A002.h., 3A501.b.13., 3A501.f., 3A501.h. or 3B.
- 3D002 "Software" specially designed for the "use" of equipment specified in 3A225, 3B001.a. to 3B001.f., 3B002, 3B501.a.4., 3B501.f.1., 3B501.k. or 3B501.n. to 3B501.r.
- 3D003 'Computational lithography' "software" specially designed for the "development" of patterns on EUV-lithography masks or reticles.

Technical Note:

For the purposes of 3D003, 'computational lithography' is the use of computer modelling to predict, correct, optimise and verify imaging performance of the lithography process over a range of patterns, processes, and system conditions.

- 3D004 "Software" specially designed for the "development" of equipment specified in 3A003.
- 3D005 "Software" specially designed to restore normal operation of a microcomputer, "microprocessor microcircuit" or "microcomputer microcircuit" within 1 ms after an Electromagnetic Pulse (EMP) or Electrostatic Discharge (ESD) disruption, without loss of continuation of operation.
- 3D006 'Electronic Computer-Aided Design' ('ECAD') "software" specially designed for the "development" of integrated circuits having any "Gate-All-Around Field-Effect Transistor" ("GAAFET") structure, and having any of the following:
- Specially designed for implementing 'Register Transfer Level' ('RTL') to 'Geometrical Database Standard II' ('GDSII') or equivalent standard; or
 - Specially designed for optimisation of power or timing rules.

Technical Notes:

For the purposes of 3D006:

- 'ECAD' is a category of "software" tools used for designing, analysing, optimising, and validating the performance of integrated circuit or printed circuit board.*
 - 'RTL' is a design abstraction which models a synchronous digital circuit in terms of the flow of digital signals between hardware registers, and the logical operations performed on those signals.*
 - 'GDSII' is a database file format for data exchange of integrated circuit or integrated circuit layout artwork.*
- 3D101 "Software" specially designed or modified for the "use" of equipment specified in 3A101.b.
- 3D225 "Software" specially designed to enhance or release the performance of frequency changers or generators to meet the characteristics of 3A225.
- 3D507 "Software" designed to extract 'GDSII' or equivalent standard layout data and perform layer-to-layer alignment from Scanning Electron Microscope (SEM) images, and generate multi-layer 'GDSII' data or the circuit netlist.

Technical Note:

For the purposes of 3D507, 'GDSII' ('Graphic Design System II') is a database file format for data exchange of integrated circuit artwork or integrated circuit layout artwork.

3E Technology

Note: 3E001 and 3E505 do not control 'Process Design Kits' ('PDKs') unless they include libraries implementing functions or technologies for items specified in 3A001 or 3A501.

Technical Note:

For the purposes of 3E001 and 3E505, a 'Process Design Kit' ('PDK') is a software tool provided by a semiconductor manufacturer to ensure that the required design practices and rules are taken into account in order to successfully produce a specific integrated circuit design in a specific semiconductor process, in accordance with technological and manufacturing constraints (each semiconductor manufacturing process has its particular 'PDK').

3E001 "Technology" according to the General Technology Note for the "development" or "production" of equipment or materials specified in 3A001, 3A002, 3A101, 3A102, 3A201, 3A225 to 3A234, 3A501, 3A502, 3A504, 3B or 3C.

Note 1: Not used.

Note 2: 3E001 does not control "technology" for integrated circuits specified in 3A001.a.3. to 3A001.a.12., having all of the following:

- a. Using "technology" at or above 0,130 μm ; and
- b. Incorporating multi-layer structures with three or fewer metal layers.

Note 3: Not used.

3E002 "Technology" according to the General Technology Note, other than that specified in 3E001, for the "development" or "production" of a "microprocessor microcircuit", "microcomputer microcircuit" or microcontroller microcircuit core, having an Arithmetic Logic Unit (ALU) with an access width of 32 bits or more and any of the following features or characteristics:

- a. A 'vector processor unit' designed to perform more than two calculations on 'floating-point' vectors (one-dimensional arrays of 32-bit or larger numbers) simultaneously;

Technical Note:

For the purposes of 3E002.a., a 'vector processor unit' is a processor element with built-in instructions that perform multiple calculations on 'floating-point' vectors (one-dimensional arrays of 32-bit or larger numbers) simultaneously, having at least one vector ALU and vector registers of at least 32 elements each.

- b. Designed to perform more than four 64-bit or larger 'floating-point' operation results per cycle; or
- c. Designed to perform more than eight 16-bit 'fixed-point' multiply-accumulate results per cycle (e.g., digital manipulation of analogue information that has been previously converted into digital form, also known as digital "signal processing").

Technical Notes:

1. For the purposes of 3E002.a. and 3E002.b., 'floating-point' is defined by IEEE-754.

2. *For the purposes of 3E002.c., 'fixed-point' refers to a fixed-width real number with both an integer component and a fractional component, and which does not include integer-only formats.*

Note 1: *3E002 does not control "technology" for multimedia extensions.*

Note 2: *3E002 does not control "technology" for micro-processor cores, having all of the following:*

- a. Using "technology" at or above 0,130 μm ; and*
- b. Incorporating multi-layer structures with five or fewer metal layers.*

Note 3: *3E002 includes "technology" for the "development" or "production" of digital signal processors and digital array processors.*

- 3E003 Other "technology" for the "development" or "production" of the following:
- a. Vacuum microelectronic devices;
 - b. Hetero-structure semiconductor electronic devices such as High Electron Mobility Transistors (HEMTs), Heterojunction Bipolar Transistors (HBTs), quantum well and super lattice devices;
Note: 3E003.b. does not control "technology" for HEMTs operating at frequencies lower than 31,8 GHz and HBTs operating at frequencies lower than 31,8 GHz.
 - c. "Superconductive" electronic devices;
 - d. Substrates 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. "Vacuum electronic devices" operating at frequencies of 31,8 GHz or higher;
 - h. Substrates of gallium oxide for electronic components.
- 3E004 "Technology" "required" for the slicing, grinding and polishing of 300 mm diameter silicon wafers to achieve a 'Site Front least sQuares Range' ('SFQR') less than or equal to 20 nm at any site of 26 mm x 8 mm on the front surface of the wafer and an edge exclusion less than or equal to 2 mm.

Technical Note:

For the purposes of 3E004 'SFQR' is the range of maximum deviation and minimum deviation from front reference plane, calculated by least square method with all front surface data including site boundary within a site.

- 3E101 "Technology" according to the General Technology Note for the "use" of equipment or "software" specified in 3A001.a.1., 3A001.a.2., 3A101, 3A102 or 3D101.
- 3E102 "Technology" according to the General Technology Note for the "development" of "software" specified in 3D101.
- 3E201 "Technology" according to the General Technology Note for the "use" of equipment specified in 3A001.e.2., 3A001.e.3., 3A001.g., 3A201, 3A225 to 3A234.
- 3E225 "Technology", in the form of codes or keys, to enhance or release the performance of frequency changers or generators to meet the characteristics of 3A225.
- 3E505 "Technology" according to the General Technology Note for the "development" or "production" of integrated circuits or devices, using "Gate-All-Around Field-Effect Transistor" ("GAAFET") structures.

Note 1: 3E505 includes 'process recipes'.

Note 2: 3E505 does not apply for tool qualification or maintenance.

Note 3: Not used.

Technical Note:

For the purposes of 3E505, a 'process recipe' is a set of conditions and parameters for a particular process step.

PART VI – Category 4

CATEGORY 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 5D001.

Technical Note:

For the purposes of Note 2, 'main storage' is the primary storage for data or instructions for rapid access by a central processing unit. It consists of the internal storage of a "digital computer" and any hierarchical extension thereto, such as cache storage or non-sequentially accessed extended storage.

4A Systems, Equipment and Components

4A001 Electronic computers and related equipment, having any of the following and "electronic assemblies" and specially designed components therefor:

N.B. SEE ALSO 4A101.

a. Specially designed to have any of the following:

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

Note: 4A001.a.1. does not control computers specially designed for civil automobile, railway train or "civil aircraft" applications.

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

- a. Total Dose 5×10^3 Gy (silicon);
- b. Dose Rate Upset 5×10^6 Gy (silicon)/s; or
- c. Single Event Upset 1×10^{-8} Error/bit/day;

Note: 4A001.a.2. does not control computers specially designed for "civil aircraft" applications.

b. Not used.

4A003 "Digital computers", "electronic assemblies", and related equipment therefor, as follows and specially designed components therefor:

Note 1: 4A003 includes the following:

- 'Vector processors';
- Array processors;
- Digital signal processors;
- Logic processors;
- Equipment designed for "image enhancement".

Note 2: The control status of the "digital computers" and related equipment described in 4A003 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 4E.

4A003 continued

- a. Not used;
- b. "Digital computers" having an "Adjusted Peak Performance" ("APP") exceeding 70 Weighted TeraFLOPS (WT);
- c. "Electronic assemblies" specially designed or modified for enhancing performance by aggregation of processors so that the "APP" of the aggregation exceeds the limit specified in 4A003.b.;

Note 1: 4A003.c. controls only "electronic assemblies" and programmable interconnections not exceeding the limit specified in 4A003.b. when shipped as unintegrated "electronic assemblies".

Note 2: 4A003.c. does not control "electronic assemblies" specially designed for a product or family of products whose maximum configuration does not exceed the limit specified in 4A003.b.

- d. Not used;
- e. Not used;
- f. Not used;
- g. Equipment specially designed for aggregating the performance of "digital computers" by providing external interconnections which allows communications at unidirectional data rates exceeding 2,0 Gbyte/s per link.

Note: 4A003.g. does not control internal interconnection equipment (e.g. backplanes, buses), passive interconnection equipment, 'network access controllers' or 'communications channel controllers'.

Technical Notes:

For the purposes of 4A003.g. Note:

1. A 'network access controller' is a physical interface to a distributed switching network. It uses a common medium which operates throughout at the same "digital transfer rate" using arbitration (e.g., token or carrier sense) for transmission. Independently from any other, it selects data packets or data groups (e.g., IEEE 802) addressed to it. It is an assembly that can be integrated into computer or telecommunications equipment to provide communications access.
2. A 'communications channel controller' is the physical interface which controls the flow of synchronous or asynchronous digital information. It is an assembly that can be integrated into computer or telecommunications equipment to provide communications access.

4A004 Computers as follows and specially designed related equipment, "electronic assemblies" and components therefor:

- a. 'Systolic array computers';
- b. 'Neural computers';
- c. 'Optical computers'.

Technical Notes:

1. *For the purposes of 4A004.a., 'systolic array computers' are computers where the flow and modification of the data is dynamically controllable at the logic gate level by the user.*
2. *For the purposes of 4A004.b., 'neural computers' are computational devices designed or modified to mimic the behaviour of a neuron or a collection of neurons, i.e., computational devices which are distinguished by their hardware capability to modulate the weights and numbers of the interconnections of a multiplicity of computational components based on previous data.*
3. *For the purposes of 4A004.c., 'optical computers' are computers designed or modified to use light to represent data and whose computational logic elements are based on directly coupled optical devices.*

4A005 Systems, equipment, and components therefor, specially designed or modified for the generation, command and control, or delivery of "intrusion software".

4A101 Analogue computers, "digital computers" or digital differential analysers, other than those specified in 4A001.a.1., which are ruggedized and designed or modified for use in space launch vehicles specified in 9A004 or sounding rockets specified in 9A104.

4A102 Hybrid computers specially designed for modelling, simulation or design integration of space launch vehicles specified in 9A004 or sounding rockets specified in 9A104.

Note: *This control only applies when the equipment is supplied with "software" specified in 7D103 or 9D103.*

4A506 Quantum computers and related "electronic assemblies" and components therefor, as follows:

- a. Quantum computers, as follows:
 1. Quantum computers supporting 34 or more, but fewer than 100, 'fully controlled', 'connected' and 'working' 'physical qubits', and having a 'C-NOT error' of less than or equal to 10^{-4} ;
 2. Quantum computers supporting 100 or more, but fewer than 200, 'fully controlled', 'connected' and 'working' 'physical qubits', and having a 'C-NOT error' of less than or equal to 10^{-3} ;
 3. Quantum computers supporting 200 or more, but fewer than 350, 'fully controlled', 'connected' and 'working' 'physical qubits', and having a 'C-NOT error' of less than or equal to 2×10^{-3} ;
 4. Quantum computers supporting 350 or more, but fewer than 500, 'fully controlled', 'connected' and 'working' 'physical qubits', and having a 'C-NOT error' of less than or equal to 3×10^{-3} ;

5. Quantum computers supporting 500 or more, but fewer than 700, 'fully controlled', 'connected' and 'working' 'physical qubits', and having a 'C-NOT error' of less than or equal to 4×10^{-3} ;
6. Quantum computers supporting 700 or more, but fewer than 1 100, 'fully controlled', 'connected' and 'working' 'physical qubits', and having a 'C-NOT error' of less than or equal to 5×10^{-3} ;
7. Quantum computers supporting 1 100 or more, but fewer than 2 000, 'fully controlled', 'connected' and 'working' 'physical qubits', and having a 'C-NOT error' of less than or equal to 6×10^{-3} ;
8. Quantum computers supporting 2 000 or more 'fully controlled', 'connected' and 'working' 'physical qubits';
- b. Qubit devices and qubit circuits, containing or supporting arrays of 'physical qubits', and specially designed for items specified in 4A506.a.;
- c. Quantum control components and quantum measurement devices, specially designed for items specified in 4A506.a.;

Note 1: 4A506 applies to circuit model (or gate-based) and one-way (or measurement-based) quantum computers. This entry does not apply to adiabatic (or annealing) quantum computers.

Note 2: Items specified in 4A506 may not necessarily physically contain any qubits. For example, quantum computers based on photonic schemes do not permanently contain a physical item that can be identified as a qubit. Instead, the photonic qubits are generated while the computer is operating and then later discarded.

Note 3: Items specified in 4A506.b. include semiconductor, superconducting, and photonic qubit chips and chip arrays; surface ion trap arrays; other qubit confinement technologies; and coherent interconnects between such items.

Note 4: 4A506.c. applies to items designed for calibrating, initialising, manipulating or measuring the resident qubits of a quantum computer.

Technical Notes:

For the purposes of 4A506:

1. A 'physical qubit' is a two-level quantum system used to represent the elementary unit of quantum logic by means of manipulations and measurements that are not error corrected. 'Physical qubits' are distinguished from logical qubits, in that logical qubits are error-corrected qubits comprised of many 'physical qubits'.
2. 'Fully controlled' means the 'physical qubit' can be calibrated, initialised, gated, and read out, as necessary.
3. 'Connected' means that two-qubit gate operations can be performed between any arbitrary pair of the available 'working' 'physical qubits'. This does not necessarily entail all-to-all connectivity.
4. 'Working' means that the 'physical qubit' performs universal quantum computational work according to the system specifications for qubit operational fidelity.

5. *Supporting 34 or more 'fully controlled', 'connected', 'working' 'physical qubits' refers to the capability of a quantum computer to confine, control, measure and process the quantum information embodied in 34 or more 'physical qubits'.*
6. *'C-NOT error' is the average physical gate error for the nearest-neighbour two-'physical qubit' Controlled-NOT (C-NOT) gates.*

4A507 Computers, "electronic assemblies", and components containing one or more integrated circuits, specified in 3A501.a.16.

Technical Note:

For the purposes of 4A507, computers include "digital computers", hybrid computers, and analogue computers.

4B Test, Inspection and Production Equipment

None.

4C Materials

None.

4D Software

Note: The control status of "software" for equipment described in other Categories is dealt with in the appropriate Category.

4D001 "Software" as follows:

- a. "Software" specially designed or modified for the "development" or "production" of equipment or "software" specified in 4A001, 4A003 to 4A005, 4A507 or 4D004;
- b. "Software", other than that specified in 4D001.a., specially designed or modified for the "development" or "production" of equipment as follows:
 1. "Digital computers" having an "Adjusted Peak Performance" ("APP") exceeding 24 Weighted TeraFLOPS (WT);
 2. "Electronic assemblies" specially designed or modified for enhancing performance by aggregation of processors so that the "APP" of the aggregation exceeds the limit in 4D001.b.1.;
 3. Items specified in 4A506.b. or 4A506.c.

4D002 Not used.

4D003 Not used.

4D004 "Software" specially designed or modified for the generation, command and control, or delivery of "intrusion software".

Note: 4D004 does not control "software" specially designed and limited to provide "software" updates or upgrades meeting all the following:

- a. *The update or upgrade operates only with the authorisation of the owner or administrator of the system receiving it; and*
- b. *After the update or upgrade, the "software" updated or upgraded is not any of the following:*
 1. *"Software" specified in 4D004; or*
 2. *"Intrusion software".*

4E Technology

4E001 "Technology" as follows:

- a. "Technology" according to the General Technology Note, for the "development", "production" or "use" of equipment or "software" specified in 4A001, 4A003 to 4A005, 4A101, 4A102, 4A507 or 4D;
- b. "Technology", according to the General Technology Note, other than that specified in 4E001.a., for the "development" or "production" of equipment as follows:
 1. "Digital computers" having an "Adjusted Peak Performance" ("APP") exceeding 24 Weighted TeraFLOPS (WT);
 2. "Electronic assemblies" specially designed or modified for enhancing performance by aggregation of processors so that the "APP" of the aggregation exceeds the limit in 4E001.b.1.;
 3. Items specified in 4A506.b. or 4A506.c.
- c. "Technology" for the "development" of "intrusion software".

Note 1: 4E001.a. and 4E001.c. do not control "vulnerability disclosure" or "cyber incident response".

Note 2: Note 1 does not diminish the rights of the competent authority of the Member State in which the exporter is established to ascertain compliance with 4E001.a. and 4E001.c.

TECHNICAL NOTE ON "ADJUSTED PEAK PERFORMANCE" ("APP")

"APP" is an adjusted peak rate at which "digital computers" perform 64-bit or larger floating point additions and multiplications.

"APP" is expressed in Weighted TeraFLOPS (WT), in units of 10^{12} adjusted Floating Point Operations (FPO) per second.

Abbreviations used in this Technical Note

n	number of processors in the "digital computer"
i	processor number (i,...n)
t_i	processor cycle time ($t_i = 1/F_i$)
F_i	processor frequency
R_i	peak floating point calculating rate
W_i	architecture adjustment factor

Outline of "APP" calculation method

1. For each processor i, determine the peak number of 64-bit or larger floating point operations, FPO_i , performed per cycle for each processor in the "digital computer".

Note: In determining FPO, include only 64-bit or larger floating point additions or multiplications. All floating point operations must be expressed in operations per processor cycle; operations requiring multiple cycles may be expressed in fractional results per cycle. For processors not capable of performing calculations on floating point operands of 64-bit or more, the effective calculating rate R is zero.

2. Calculate the floating point rate R for each processor $R_i = FPO_i/t_i$.
3. Calculate "APP" as "APP" = $W_1 \times R_1 + W_2 \times R_2 + \dots + W_n \times R_n$.
4. For 'vector processors', $W_i = 0,9$. For non-'vector processors', $W_i = 0,3$.

Note 1: For processors that perform compound operations in a cycle, such as addition and multiplication, each operation is counted.

Note 2: For a pipelined processor the effective calculating rate R is the faster of the pipelined rate, once the pipeline is full, or the non-pipelined rate.

Note 3: The calculating rate R of each contributing processor is to be calculated at its maximum value theoretically possible before the "APP" of the combination is derived. 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: Do not include processors that are limited to input/output and peripheral functions (e.g., disk drive, communication and video display) when calculating "APP".

Note 5: "APP" values are not to be calculated for processor 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".

Note 6: "APP" values must be calculated for processor combinations containing processors specially designed to enhance performance by aggregation, operating simultaneously and sharing memory.

Technical Notes:

1. Aggregate all processors and accelerators operating simultaneously and located on the same die.
2. Processor combinations share memory when any processor is capable of accessing any memory location in the system through the hardware transmission of cache lines or memory words, without the involvement of any software mechanism, which may be achieved using "electronic assemblies" specified in 4A003.c.

Note 7: A 'vector processor' is defined as a processor with built-in instructions that perform multiple calculations on floating-point vectors (one-dimensional arrays of 64-bit or larger numbers) simultaneously, having at least 2 vector functional units and at least 8 vector registers of at least 64 elements each.

PART VII – Category 5

CATEGORY 5 - TELECOMMUNICATIONS AND "INFORMATION SECURITY"

Part 1 - TELECOMMUNICATIONS

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

N.B. *For "lasers" specially designed for telecommunications equipment or systems, see 6A005.*

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.*

5A1 Systems, Equipment and Components

5A001 Telecommunications systems, equipment, components and accessories as follows:

- 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;
 - 3. Specially designed to operate below 218 K (-55°C); or
 - 4. Specially designed to operate above 397 K (124°C);

Note 1: *5A001.a.3. and 5A001.a.4. control only electronic equipment.*

Note 2: *5A001.a.2., 5A001.a.3. and 5A001.a.4. do not control equipment designed or modified for use on board "spacecraft".*

5A001 continued

- b. Telecommunication systems and equipment, and specially designed components and accessories therefor, having any of the following characteristics, functions or features:
 - 1. Being underwater untethered communications systems having any of the following:
 - a. An acoustic carrier frequency outside the range from 20 kHz to 60 kHz;
 - b. Using an electromagnetic carrier frequency below 30 kHz;
 - c. Using electronic beam steering techniques; or
 - d. Using "lasers" or light-emitting diodes (LEDs) with an output wavelength greater than 400 nm and less than 700 nm, in a "local area network";
 - 2. Being radio equipment operating in the 1,5 MHz to 87,5 MHz band and having all of the following:
 - a. Automatically predicting and selecting frequencies and "total digital transfer rates" per channel to optimise the transmission; and
 - b. 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 less(better) than -80 dB;

5A001.b. continued

3. Being radio equipment employing "spread spectrum" techniques, including "frequency hopping" techniques, other than those specified in 5A001.b.4. and having any of the following:

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

Note: 5A001.b.3.b. does not control radio equipment specially designed for use with any of the following:

- a. Civil cellular radio-communications systems; or*
- b. Fixed or mobile "satellite" earth stations for commercial civil telecommunications.*

Note: 5A001.b.3 does not control equipment designed to operate at an output power of 1 W or less.

4. Being radio equipment employing ultra-wideband modulation techniques, having user programmable channelising codes, scrambling codes or network identification codes and having any of the following:

- a. A bandwidth exceeding 500 MHz; or
- b. A "fractional bandwidth" of 20% or more;

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

- a. More than 1 000 channels;
- b. A 'channel switching time' of less than 1 ms;
- c. Automatic searching or scanning of a part of the electromagnetic spectrum; and
- d. Identification of the received signals or the type of transmitter; or

Note: 5A001.b.5. does not control radio equipment specially designed for use with civil cellular radio-communications systems.

Technical Note:

For the purposes of 5A001.b.5.b., 'channel switching time' means the time (i.e., delay) to change from one receiving frequency to another, to arrive at or within $\pm 0,05\%$ of the final specified receiving frequency. Items having a specified frequency range of less than $\pm 0,05\%$ around their centre frequency are defined to be incapable of channel frequency switching.

5A001.b. continued

6. Employing functions of digital "signal processing" to provide 'voice coding' output at rates of less than 700 bit/s;

Technical Notes:

1. *For variable rate 'voice coding', 5A001.b.6. applies to the 'voice coding' output of continuous speech.*
2. *For the purposes of 5A001.b.6., 'voice coding' is defined as the technique to take samples of human voice and then convert these samples into a digital signal, taking into account specific characteristics of human speech.*

- c. Optical fibres of more than 500 m in length and specified by the manufacturer as being capable of withstanding a 'proof test' tensile stress of $2 \times 10^9 \text{ N/m}^2$ or more;

N.B. *For underwater umbilical cables, see 8A002.a.3.*

Technical Note:

For the purposes of 5A001.c., 'proof test' is the 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 (20°C) and relative humidity 40%. Equivalent national standards may be used for executing the proof test.

5A001 continued

- d. 'Electronically steerable phased array antennae' as follows:
1. Rated for operation above 31,8 GHz but not exceeding 57 GHz, and having an Effective Radiated Power (ERP) equal to or greater than +20 dBm (22,15 dBm Effective Isotropic Radiated Power (EIRP));
 2. Rated for operation above 57 GHz but not exceeding 66 GHz, and having an ERP equal to or greater than +24 dBm (26,15 dBm EIRP);
 3. Rated for operation above 66 GHz but not exceeding 90 GHz, and having an ERP equal to or greater than +20 dBm (22,15 dBm EIRP);
 4. Rated for operation above 90 GHz;

Note 1: 5A001.d. does not control 'electronically steerable phased array antennae' for landing systems with instruments meeting International Civil Aviation Organization (ICAO) standards covering Microwave Landing Systems (MLS).

Note 2: 5A001.d. does not control antennae specially designed for any of the following:

- a. Civil cellular or WLAN radio-communications systems;
- b. IEEE 802.15 or wireless HDMI; or
- c. Fixed or mobile "satellite" earth stations for commercial civil telecommunications.

Technical Note:

For the purposes of 5A001.d., 'electronically steerable phased array antenna' is an antenna which forms a beam by means of phase coupling, (i.e., the beam direction is controlled by the complex excitation coefficients of the radiating elements) and the direction of that beam can be varied (both in transmission and reception) in azimuth or in elevation, or both, by application of an electrical signal.

5A001 continued

- e. Radio direction finding equipment operating at frequencies above 30 MHz and having all of the following, and specially designed components therefor:
 - 1. "Instantaneous bandwidth" of 10 MHz or more; and
 - 2. Capable of finding a Line Of Bearing (LOB) to non-cooperating radio transmitters with a signal duration of less than 1 ms;
- f. Mobile telecommunications interception or jamming equipment, and monitoring equipment therefor, as follows, and specially designed components therefor:
 - 1. Interception equipment designed for the extraction of voice or data, transmitted over the air interface;
 - 2. Interception equipment not specified in 5A001.f.1., designed for the extraction of client device or subscriber identifiers (e.g., International Mobile Subscriber Identity (IMSI), Temporary International Mobile Subscriber Identity (TIMSI) or International Mobile Equipment Identity (IMEI)), signalling, or other metadata transmitted over the air interface;
 - 3. Jamming equipment specially designed or modified to intentionally and selectively interfere with, deny, inhibit, degrade or seduce mobile telecommunication services and performing any of the following:
 - a. Simulate the functions of Radio Access Network (RAN) equipment;
 - b. Detect and exploit specific characteristics of the mobile telecommunications protocol employed (e.g., GSM); or
 - c. Exploit specific characteristics of the mobile telecommunications protocol employed (e.g. GSM);
 - 4. Radio Frequency (RF) monitoring equipment designed or modified to identify the operation of items specified in 5A001.f.1., 5A001.f.2. or 5A001.f.3.;

Note: 5A001.f.1. and 5A001.f.2. do not control any of the following:

- a. Equipment specially designed for the interception of analogue Private Mobile Radio (PMR), IEEE 802.11 WLAN;
- b. Equipment designed for mobile telecommunications network operators; or
- c. Equipment designed for the "development" or "production" of mobile telecommunications equipment or systems.

N.B.1. SEE ALSO MILITARY GOODS CONTROLS.

N.B.2. For radio receivers, see 5A001.b.5.

5A001 continued

- g. Passive Coherent Location (PCL) systems or equipment, specially designed for detecting and tracking moving objects by measuring reflections of ambient radio frequency emissions, supplied by non-radar transmitters;

Technical Note:

For the purposes of 5A001.g., non-radar transmitters may include commercial radio, television or cellular telecommunications base stations.

Note: 5A001.g. does not control any of the following:

- a. Radio-astronomical equipment; or
 - b. Systems or equipment, that require any radio transmission from the target.
- h. Counter Improvised Explosive Device (IED) equipment and related equipment, as follows:
 - 1. Radio Frequency (RF) transmitting equipment, not specified in 5A001.f., designed or modified for prematurely activating or preventing the initiation of Improvised Explosive Devices (IEDs);
 - 2. Equipment using techniques designed to enable radio communications in the same frequency channels on which co-located equipment specified in 5A001.h.1. is transmitting;

N.B. SEE ALSO MILITARY GOODS CONTROLS.

- i. Not used;
- j. Internet Protocol (IP) network communications surveillance systems or equipment, and specially designed components therefor, having all of the following:
 - 1. Performing all of the following on a carrier class Internet Protocol (IP) network (e.g., national grade IP backbone):
 - a. Analysis at the application layer (e.g., Layer 7 of Open Systems Interconnection (OSI) model (ISO/IEC 7498-1));
 - b. Extraction of selected metadata and application content (e.g., voice, video, messages, attachments); and
 - c. Indexing of extracted data; and

5A001.j. continued

2. Being specially designed to carry out all of the following:
 - a. Execution of searches on the basis of "hard selectors"; and
 - b. Mapping of the relational network of an individual or of a group of people.

Note: 5A001.j. does not control systems or equipment, specially designed for any of the following:

- a. Marketing purpose;*
- b. Network Quality of Service (QoS); or*
- c. Quality of Experience (QoE).*

5A101 Telemetry and telecontrol equipment, including ground equipment, designed or modified for 'missiles'.

Technical Note:

In 5A101 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.

Note: 5A101 does not control:

- a. Equipment designed or modified for manned aircraft or satellites;*
- b. Ground based equipment designed or modified for terrestrial or marine applications;*
- c. Equipment designed for commercial, civil or 'Safety of Life' (e.g. data integrity, flight safety) navigation satellite systems services;*

5B1 Test, Inspection and Production Equipment

5B001 Telecommunications test, inspection and production equipment, components and accessories, as follows:

- a. Equipment and specially designed components or accessories therefor, specially designed for the "development" or "production" of equipment, functions or features, specified in 5A001;

Note: 5B001.a. does not control optical fibre characterization equipment.

- 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. Not used;
2. Equipment employing a "laser" and having any of the following:
 - a. A transmission wavelength exceeding 1 750 nm; or
 - b. Not used;
 - c. Not used;
 - d. Employing analogue techniques and having a bandwidth exceeding 2,5 GHz; or

Note: 5B001.b.2.d. does not control equipment specially designed for the "development" of commercial TV systems.

3. Not used;
4. Radio equipment employing Quadrature-Amplitude-Modulation (QAM) techniques above level 1 024;
5. Not used.

5C1 Materials

None

5D1 Software

5D001 "Software" as follows:

- a. "Software" specially designed or modified for the "development", "production" or "use" of equipment, functions or features, specified in 5A001;
- b. Not used;
- c. Specific "software" specially designed or modified to provide characteristics, functions or features of equipment, specified in 5A001 or 5B001;
- d. "Software" specially designed or modified for the "development" of any of the following telecommunication transmission or switching equipment:
 1. Not used;
 2. Equipment employing a "laser" and having any of the following:
 - a. A transmission wavelength exceeding 1 750 nm; or
 - b. Employing analogue techniques and having a bandwidth exceeding 2,5 GHz; or

Note: 5D001.d.2.b. does not control "software" specially designed or modified for the "development" of commercial TV systems.
 3. Not used;
 4. Radio equipment employing Quadrature-Amplitude-Modulation (QAM) techniques above level 1 024;

5D001 continued

- e. "Software", other than that specified in 5D001.a. or 5D001.c., specially designed or modified for monitoring or analysis for law enforcement purposes, providing all of the following:
 - 1. Execution of searches on the basis of "hard selectors" of either the content of communication or metadata acquired from a communications service provider using a 'handover interface'; and
 - 2. Mapping of the relational network or tracking the movement or location of targeted individuals based on the results of searches on content of communication or metadata or searches as described in 5D001.e.1.

Technical Notes:

- 1. *For the purposes of 5D001.e., a 'handover interface' is a physical and logical interface, designed for use by an authorised law enforcement authority, across which targeted interception measures are requested from a communications service provider and the results of interception are delivered from a communications service provider to the requesting authority. The 'handover interface' is implemented within systems or equipment (e.g., mediation devices) that receive and validate the interception request, and deliver to the requesting authority only the results of interception that fulfil the validated request.*
- 2. *'Handover interfaces' may be specified in international standards (including but not limited to ETSI TS 101 331, ETSI TS 101 671, 3GPP TS 33.108) or national equivalents.*

5D001.e. continued

Note: 5D001.e. does not control "software" specially designed or modified for any of the following:

- a. Billing purposes;
- b. Network Quality of Service (QoS);
- c. Quality of Experience (QoE);
- d. Mediation devices; or
- e. Mobile payment or banking use.

5D101 "Software" specially designed or modified for the "use" of equipment specified in 5A101.

5E1 Technology

5E001 "Technology" as follows:

- a. "Technology" according to the General Technology Note for the "development", "production" or "use" (excluding operation) of equipment, functions or features specified in 5A001 or "software" specified in 5D001.a. or 5D001.e.;
- b. Specific "technology" as follows:
 1. "Technology" "required" for the "development" or "production" of telecommunications equipment specially designed to be used on board "spacecraft";
 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";

5E001.b. continued

4. "Technology" for the "development" of "spread spectrum" techniques, including "frequency hopping" techniques;

Note: 5E001.b.4. does not control "technology" for the "development" of any of the following:

- a. Civil cellular radio-communications systems; or*
- b. Fixed or mobile satellite earth stations for commercial civil telecommunications.*

5E001 continued

- c. "Technology" according to the General Technology Note for the "development" or "production" of any of the following:
 - 1. Not used;
 - 2. Equipment employing a "laser" and having any of the following:
 - a. A transmission wavelength exceeding 1 750 nm; or
 - b. Not used;
 - c. Not used;
 - d. Employing wavelength division multiplexing techniques of optical carriers at less than 100 GHz spacing; or
 - e. Employing analogue techniques and having a bandwidth exceeding 2,5 GHz;

Note: 5E001.c.2.e. does not control "technology" for commercial TV systems.

N.B. For "technology" for the "development" or "production" of non-telecommunications equipment employing a laser, see 6E.

5E001.c. continued

3. Equipment employing 'optical switching' and having a switching time less than 1 ms;

Technical Note:

For the purposes of 5E001.c.3., 'optical switching' is the routing of or switching of signals in optical form without conversion to electrical signals.

4. Radio equipment having any of the following:
 - a. Quadrature-Amplitude-Modulation (QAM) techniques above level 1 024;
 - b. Operating at input or output frequencies exceeding 31,8 GHz; or

Note: 5E001.c.4.b. does not control "technology" for equipment designed or modified for operation in any frequency band which is "allocated by the International Telecommunication Union (ITU)" for radio-communications services, but not for radio-determination.

- c. Operating in the 1,5 MHz to 87,5 MHz band and incorporating adaptive techniques providing more than 15 dB suppression of an interfering signal; or

5. Not used;

6. Mobile equipment having all of the following:

- a. Operating at an optical wavelength greater than or equal to 200 nm and less than or equal to 400 nm; and
 - b. Operating as a "local area network";

- d. "Technology" according to the General Technology Note for the "development" or "production" of "Monolithic Microwave Integrated Circuit" ("MMIC") amplifiers specially designed for telecommunications and that are any of the following:

Technical Note:

For the purposes of 5E001.d., the parameter peak saturated power output may also be referred to on product data sheets as output power, saturated power output, maximum power output, peak power output, or peak envelope power output.

5E001.d. continued

1. Rated for operation at frequencies exceeding 2,7 GHz up to and including 6,8 GHz with a "fractional bandwidth" greater than 15%, and having any of the following:
 - a. A peak saturated power output greater than 75 W (48,75 dBm) at any frequency exceeding 2,7 GHz up to and including 2,9 GHz;
 - b. A peak saturated power output greater than 55 W (47,4 dBm) at any frequency exceeding 2,9 GHz up to and including 3,2 GHz;

5E001.d.1. continued

- c. A peak saturated power output greater than 40 W (46 dBm) at any frequency exceeding 3,2 GHz up to and including 3,7 GHz; or
 - d. A peak saturated power output greater than 20 W (43 dBm) at any frequency exceeding 3,7 GHz up to and including 6,8 GHz;
- 2. Rated for operation at frequencies exceeding 6,8 GHz up to and including 16 GHz with a "fractional bandwidth" greater than 10%, and having any of the following:
 - a. A peak saturated power output greater than 10W (40 dBm) at any frequency exceeding 6,8 GHz up to and including 8,5 GHz; or
 - b. A peak saturated power output greater than 5W (37 dBm) at any frequency exceeding 8,5 GHz up to and including 16 GHz;
- 3. Rated for operation with a peak saturated power output greater than 3 W (34,77 dBm) at any frequency exceeding 16 GHz up to and including 31,8 GHz, and with a "fractional bandwidth" of greater than 10%;
- 4. Rated for operation with a peak saturated power output greater than 0,1 nW (-70 dBm) at any frequency exceeding 31,8 GHz up to and including 37 GHz;
- 5. Rated for operation with a peak saturated power output greater than 1 W (30 dBm) at any frequency exceeding 37 GHz up to and including 43,5 GHz, and with a "fractional bandwidth" of greater than 10%;
- 6. Rated for operation with a peak saturated power output greater than 31,62 mW (15 dBm) at any frequency exceeding 43,5 GHz up to and including 75 GHz, and with a "fractional bandwidth" of greater than 10%;
- 7. Rated for operation with a peak saturated power output greater than 10 mW (10 dBm) at any frequency exceeding 75 GHz up to and including 90 GHz, and with a "fractional bandwidth" of greater than 5%; or
- 8. Rated for operation with a peak saturated power output greater than 0,1 nW (-70 dBm) at any frequency exceeding 90 GHz;

5E001 continued

- e. "Technology" according to the General Technology Note for the "development" or "production" of electronic devices and circuits, specially designed for telecommunications and containing components manufactured from "superconductive" materials, specially designed for operation at temperatures below the "critical temperature" of at least one of the "superconductive" constituents and having 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.

5E101 "Technology" according to the General Technology Note for the "development", "production" or "use" of equipment specified in 5A101.

5E501 "Technology" as follows:

- f. "Libraries" specially designed or modified to enable equipment to perform the functions of equipment specified in 5A001.h.

N.B. For "libraries" specially designed or modified for military use, see the Military Goods Controls.

Part 2 - "INFORMATION SECURITY"

Note 1: *Not used.*

Note 2: *Category 5, Part 2 does not control products when accompanying their user for the user's personal use.*

Note 3: Cryptography Note

5A002, 5D002.a.1., 5D002.b. and 5D002.c.1. do not control items as follows:

- a. Items that meet all of the following:*
 - 1. Generally available to the public by being sold, without restriction, from stock at retail selling points by means of any of the following:*
 - a. Over-the-counter transactions;*
 - b. Mail order transactions;*
 - c. Electronic transactions; or*
 - d. Telephone call transactions;*
 - 2. The cryptographic functionality cannot easily be changed by the user;*
 - 3. Designed for installation by the user without further substantial support by the supplier; and*
 - 4. When necessary, details of the goods are accessible and will be provided, upon request, to the competent authorities of the EU Member State in which the exporter is established in order to ascertain compliance with conditions described in points 1., 2. and 3.;*

- b. *Hardware components or 'executable software', of existing items described in point a. of this Note, that have been designed for these existing items, meeting all of the following:*
1. *"Information security" is not the primary function or set of functions of the component or 'executable software';*
 2. *The component or 'executable software' does not change any cryptographic functionality of the existing items, or add new cryptographic functionality to the existing items;*
 3. *The feature set of the component or 'executable software' is fixed and is not designed or modified to customer specification; and*
 4. *When necessary as determined by the competent authorities of the Member State in which the exporter is established, details of the component or 'executable software' and details of relevant end-items are accessible and will be provided to the competent authority upon request, in order to ascertain compliance with conditions described in points 1., 2., and 3.*

Technical Note:

For the purposes of the Cryptography Note, 'executable software' means "software" in executable form, from an existing hardware component excluded from 5A002 by the Cryptography Note.

Note: *'Executable software' does not include complete binary images of the "software" running on an end-item.*

Note to the Cryptography Note:

1. *To meet point a. of Note 3, all of the following must apply:*
 - a. *The item is of potential interest to a wide range of individuals and businesses; and*
 - b. *The price and information about the main functionality of the item are available before purchase without the need to consult the vendor or supplier. A simple price enquiry is not considered to be a consultation.*
2. *In determining eligibility of point a. of Note 3, competent authorities may take into account relevant factors such as quantity, price, required technical skill, existing sales channels, typical customers, typical use or any exclusionary practices of the supplier.*

5A2 Systems, Equipment and Components

5A002 "Information security" systems, equipment and components, as follows:

N.B. *For the control of "satellite navigation system" receiving equipment containing or employing decryption, see 7A005.*

a. Designed or modified to use 'cryptography for data confidentiality' having a 'described security algorithm', as follows:

1. Items having "information security" as a primary function;
2. Digital communication or networking systems, equipment or components, not specified in 5A002.a.1.;
3. Computers, other items having information storage or processing as a primary function, and components therefor, not specified in 5A002.a.1. or 5A002.a.2.;

N.B. *For operating systems, see also 5D002.a.1. and 5D002.c.1.*

4. Items, not specified in 5A002.a.1. to 5A002.a.3., where the 'cryptography for data confidentiality' having a 'described security algorithm' meets all of the following:

- a. It supports a non-primary function of the item; and
- b. It is performed by incorporated equipment or "software" that would, as a standalone item, be specified in Category 5, Part 2.

Technical Notes:

1. For the purposes of 5A002.a., 'cryptography for data confidentiality' means "cryptography" that employs digital techniques for a cryptographic function or capability that is usable or can be made usable, other than any of the following:
 - a. "Authentication";
 - b. Digital signature;
 - c. Data integrity;
 - d. Non-repudiation;
 - e. Digital rights management, including the execution of copy-protected "software";
 - f. Encryption or decryption in support of entertainment, mass commercial broadcasts or medical records management;
 - g. Wireless "personal area network" functionality implementing only published or commercial cryptographic standards;
 - h. Cryptographic operations specially designed for and limited to banking use or money transactions, including the collection and settlement of fares or credit functions;
 - i. Key management in support of and limited to functions and capabilities described in points a. to h.; or
 - j. Cryptographic functions or capabilities that have not been activated or enabled, and can only be activated or enabled by means of secure "cryptographic activation".

N.B. For 'cryptographic activation token' items, see 5A002.b., 5D002.b. and 5E002.b.

2. For the purposes of 5A002.a., 'described security algorithm' means any of the following:
 - a. A 'symmetric algorithm' employing a key length in excess of 56 bits, not including parity bits;

Technical Notes:

For the purposes of 5A002.a. Technical Note 2.a.:

1. 'Symmetric algorithm' is a cryptographic algorithm using an identical key for both encryption and decryption.
2. A common use of 'symmetric algorithms' is confidentiality of data.
- b. An "asymmetric algorithm" where the security of the algorithm is based on any of the following:
 1. Factorisation of integers in excess of 512 bits (e.g., RSA);
 2. Computation of discrete logarithms in a multiplicative group of a finite field of size greater than 512 bits (e.g., Diffie-Hellman over $\mathbb{Z}/p\mathbb{Z}$); or
 3. Discrete logarithms in a group other than mentioned in point b.2. in excess of 112 bits (e.g., Diffie-Hellman over an elliptic curve); or

5A002.a. Technical Note 2 continued

- c. *An "asymmetric algorithm" where the security of the algorithm is based on any of the following:*
1. *Shortest vector or closest vector problems associated with lattices (e.g., NewHope, Frodo, NTRUEncrypt, Kyber, Titanium);*
 2. *Finding isogenies between Supersingular elliptic curves (e.g., Supersingular Isogeny Key Encapsulation); or*
 3. *Decoding random codes (e.g., McEliece, Niederreiter).*

Technical Note:

An algorithm described by Technical Note 2.c. may be referred to as being post-quantum, quantum-safe or quantum-resistant.

5A002.a. continued

Note 1: *When necessary as determined by the appropriate authority in the exporter's country, details of items must be accessible and provided to the authority upon request, in order to establish any of the following:*

- a. Whether the item meets the criteria of 5A002.a.1. to 5A002.a.4.; or*
- b. Whether the 'cryptography for data confidentiality' having a 'described security algorithm' is usable without secure "cryptographic activation".*

Note 2: *5A002.a. does not control any of the following items, or specially designed "information security" components therefor:*

- a. Smart cards and smart card 'readers/writers' as follows:*
 - 1. A smart card or an electronically readable personal document (e.g., token coin, e-passport) that meets any of the following:*
 - a. The 'cryptography for data confidentiality' having a 'described security algorithm' meets all of the following:*
 - 1. It is restricted for use in equipment or systems to which 5A002.a. does not control for reasons other than the Cryptography Note (Note 3 in Category 5 – Part 2); and*
 - 2. It cannot be reprogrammed for any other use; or:*

b. Having all of the following:

- 1. It is specially designed and limited to allow protection of 'personal data' stored within;*
- 2. Has been, or can only be, personalised for public or commercial transactions or individual identification; and*
- 3. Where the 'cryptography for data confidentiality' having a 'described security algorithm' is not user-accessible;*

Technical Note:

For the purposes of 5A002.a. Note 2.a.1.b.1., 'personal data' includes any data specific to a particular person or entity, such as the amount of money stored and data necessary for "authentication".

2. *'Readers/writers'.*

Technical Note:

For the purposes of 5A002.a. Note 2.a.2., 'readers/writers' include equipment that communicates with smart cards or electronically readable documents through a network.

- b. Not used;*
- c. Portable or mobile radiotelephones designed for civil use , other than satellite telephones, that are not capable of any of the following:*
 - 1. Transmitting encrypted data directly to another radiotelephone or equipment (other than Radio Access Network (RAN) equipment); or*
 - 2. Passing encrypted data through RAN equipment (e.g., Radio Network Controller (RNC) or Base Station Controller (BSC));*
- d. Cordless telephone equipment not capable of end-to-end encryption where the maximum effective range of unboosted cordless operation (i.e. a single, unrelayed hop between terminal and home base station) is less than 400 metres according to the manufacturer's specifications;*
- e. Portable or mobile radiotelephones and similar client wireless devices, designed for civil use, that have been customised for a specific civil industry application meeting all of the following:*
 - 1. The non-customised devices satisfy the provisions of the Cryptography Note (Note 3 in Category 5 – Part 2); and*
 - 2. The 'cryptography for data confidentiality' having a 'described security algorithm' of the non-customised devices is not affected by the customisation, and implements only published or commercial cryptographic standards;*

5A002.a. Note 2 continued

- f. Not used;*
- g. Mobile telecommunications Radio Access Network (RAN) equipment designed for civil use, which also meet the provisions of points a.2., a.3. and a.4. of the Cryptography Note (Note 3 in Category 5, Part 2), having a Radio Frequency (RF) output power limited to 0,1W (20 dBm) or less, and supporting 32 or fewer concurrent users;*
- h. Routers, switches, gateways or relays, where the 'cryptography for data confidentiality' having a 'described security algorithm' is limited to the tasks of "Operations, Administration or Maintenance" ("OAM") implementing only published or commercial cryptographic standards;*
- i. General purpose computing equipment or servers, where the 'cryptography for data confidentiality' having a 'described security algorithm' meets all of the following:*
 - 1. Implements only published or commercial cryptographic standards; and*
 - 2. Is any of the following:*
 - a. Integral to a Central Processing Unit (CPU) that meets the provisions of Note 3 to Category 5, Part 2;*
 - b. Integral to an operating system to which 5D002 does not control; or*
 - c. Limited to "OAM" of the equipment ; or*

- j. *Items specially designed for a 'connected civil industry application', meeting all of the following:*
1. *Being any of the following:*
 - a. *A network-capable endpoint device meeting any of the following:*
 1. *The 'cryptography for data confidentiality' having a 'described security algorithm' is limited to securing 'non-arbitrary data' or the tasks of "Operations, Administration or Maintenance" ("OAM"); or*
 2. *The device is limited to a specific 'connected civil industry application'; or*
 - b. *Networking equipment meeting all of the following:*
 1. *Being specially designed to communicate with the devices specified in point j.1.a. ; and*
 2. *The 'cryptography for data confidentiality' having a 'described security algorithm' is limited to supporting the 'connected civil industry application' of devices specified in point j.1.a. , or the tasks of "OAM" of this networking equipment or of other items specified in point j. of this Note; and*
 2. *Where the 'cryptography for data confidentiality' having a 'described security algorithm' implements only published or commercial cryptographic standards, and the cryptographic functionality cannot easily be changed by the user.*

Technical Notes:

1. *For the purposes of 5A002.a. Note 2.j., 'connected civil industry application' means a network connected consumer or civil industry application other than "information security", digital communication, general purpose networking or computing.*
2. *For the purposes of 5A002.a. Note 2.j.1.a.1., 'non-arbitrary data' means sensor or metering data directly related to the stability, performance or physical measurement of a system (e.g., temperature, pressure, flow rate, mass, volume, voltage, physical location etc.), that cannot be changed by the user of the device.*

5A002 continued

- b. Being a 'cryptographic activation token';

Technical Note:

For the purposes of 5A002.b., a 'cryptographic activation token' is an item designed or modified for any of the following:

- 1. Converting, by means of "cryptographic activation", an item not specified in Category 5, Part 2 into an item specified in 5A002.a. or 5D002.c.1., and not released by the Cryptography Note (Note 3 in Category 5, Part 2); or*
- 2. Enabling, by means of "cryptographic activation", additional functionality specified in 5A002.a. of an item already specified in Category 5, Part 2.*

- c. Designed or modified to use or perform "quantum cryptography";

Technical Note:

For the purposes of 5A002.c., "quantum cryptography" is also known as Quantum Key Distribution (QKD).

- d. Designed or modified to use cryptographic techniques to generate channelising codes, scrambling codes or network identification codes, for systems using ultra-wideband modulation techniques and having any of the following:

1. A bandwidth exceeding 500 MHz; or
2. A "fractional bandwidth" of 20% or more;

- e. Designed or modified to use cryptographic techniques to generate the spreading code for "spread spectrum" systems, other than those specified in 5A002.d., including the hopping code for "frequency hopping" systems.

5A003 Systems, equipment and components, for non-cryptographic "information security", as follows:

- a. Communications cable systems designed or modified to use mechanical, electrical or electronic means to detect surreptitious intrusion;

Note: 5A003.a. only controls physical layer security. For the purpose of 5A003.a., the physical layer includes Layer 1 of the Reference Model of Open Systems Interconnection (OSI) (ISO/IEC 7498-1).

- b. Specially designed or modified to reduce the compromising emanations of information-bearing signals beyond what is necessary for health, safety or electromagnetic interference standards.

5A004 Systems, equipment and components for defeating, weakening or bypassing "information security", as follows:

- a. Designed or modified to perform 'cryptanalytic functions'.

Note: 5A004.a. includes systems or equipment, designed or modified to perform 'cryptanalytic functions' by means of reverse engineering.

Technical Note:

For the purposes of 5A004.a., 'cryptanalytic functions' are functions designed to defeat cryptographic mechanisms in order to derive confidential variables or sensitive data, including clear text, passwords or cryptographic keys.

- b. Items, not specified in 4A005 or 5A004.a., designed to perform all of the following:

1. 'Extract raw data' from a computing or communications device; and
2. Circumvent "authentication" or authorisation controls of the device, in order to perform the function described in 5A004.b.1.

Technical Note:

For the purposes of 5A004.b.1., 'extract raw data' from a computing or communications device means to retrieve binary data from a storage medium (e.g., RAM, flash or hard disk) of the device without interpretation by the device's operating system or filesystem.

Note 1: 5A004.b. does not control systems or equipment specially designed for the "development" or "production" of a computing or communications device.

Note 2: 5A004.b. does not include:

- a. Debuggers, hypervisors;
- b. Items limited to logical data extraction;
- c. Data extraction items using chip-off or Joint Test Action Group (JTAG); or
- d. Items specially designed and limited to jail-breaking or rooting.

5B2 Test, Inspection and Production Equipment

5B002 "Information security" test, inspection and "production" equipment, as follows:

- a. Equipment specially designed for the "development" or "production" of equipment specified in 5A002, 5A003, 5A004 or 5B002.b.;
- b. Measuring equipment specially designed to evaluate and validate the "information security" functions of the equipment specified in 5A002, 5A003 or 5A004, or of "software" specified in 5D002.a. or 5D002.c.

5C2 Materials

None.

5D2 Software

5D002 "Software" as follows:

- a. "Software" specially designed or modified for the "development", "production" or "use" of any of the following:
 - 1. Equipment specified in 5A002 or "software" specified in 5D002.c.1.;
 - 2. Equipment specified in 5A003 or "software" specified in 5D002.c.2.; or
 - 3. Equipment or "software", as follows:
 - a. Equipment specified in 5A004.a. or "software" specified in 5D002.c.3.a.;
 - b. Equipment specified in 5A004.b. or "software" specified in 5D002.c.3.b.
- b. "Software" having the characteristics of a 'cryptographic activation token' specified in 5A002.b.;

5D002 continued

- c. "Software" having the characteristics of, or performing or simulating the functions of, any of the following:
 - 1. Equipment specified in 5A002.a., 5A002.c., 5A002.d. or 5A002.e.;
N.B. For decryption "software" relating to "satellite navigation system" receiving equipment, see 7D005.
Note: 5D002.c.1. does not control "software" limited to the tasks of "OAM" implementing only published or commercial cryptographic standards.
 - 2. Equipment specified in 5A003; or
 - 3. Equipment, as follows:
 - a. Equipment specified in 5A004.a.;
 - b. Equipment specified in 5A004.b.
Note: 5D002.c.3.b. does not control "intrusion software".
- d. Not used.

5E2 Technology

5E002 "Technology" as follows:

- a. "Technology" according to the General Technology Note for the "development", "production" or "use" of equipment specified in 5A002, 5A003, 5A004 or 5B002, or of "software" specified in 5D002.a. or 5D002.c.
N.B. For decryption "technology" relating to "satellite navigation system" receiving equipment, see 7E001.
Note: 5E002.a. does not control "technology" for items specified in 5A004.b., 5D002.a.3.b. or 5D002.c.3.b.
- b. "Technology" having the characteristics of a 'cryptographic activation token' specified in 5A002.b.
Note: 5E002 includes "information security" technical data resulting from procedures carried out to evaluate or determine the implementation of functions, features or techniques specified in Category 5, Part 2.

PART VIII – Category 6

CATEGORY 6 - SENSORS AND LASERS

6A Systems, Equipment and Components

6A001 Acoustic systems, equipment and components, as follows:

- a. Marine acoustic systems, equipment and specially designed components therefor, as follows:

1. Active (transmitting or transmitting-and-receiving) systems, equipment and specially designed components therefor, as follows:

Note: 6A001.a.1. does not control equipment as follows:

- a. *Depth sounders operating vertically below the apparatus, not including a scanning function exceeding $\pm 20^\circ$, and limited to measuring the depth of water, the distance of submerged or buried objects or fish finding;*
- b. *Acoustic beacons, as follows:*
 1. *Acoustic emergency beacons;*
 2. *Pingers specially designed for relocating or returning to an underwater position.*

- a. Acoustic seabed survey equipment as follows:

Technical Note:

For the purposes of 6A001.a.1.a., 'enhancement' includes the ability to compensate by external means.

1. Surface vessel survey equipment designed for seabed topographic mapping and having all of the following:
 - a. Designed to take measurements at an angle exceeding 20° from the vertical;
 - b. Designed to measure seabed topography at seabed depths exceeding 600 m;
 - c. 'Sounding resolution' less than 2; and

6A001.a.1.a.1. continued

- d. 'Enhancement' of the depth "accuracy" through compensation for all the following:
 - 1. Motion of the acoustic sensor;
 - 2. In-water propagation from sensor to the seabed and back; and
 - 3. Sound speed at the sensor;

Technical Note:

For the purposes of 6A001.a.1.a.1.c., 'sounding resolution' is the swath width (degrees) divided by the maximum number of soundings per swath.

2. Underwater survey equipment designed for seabed topographic mapping and having any of the following:

Technical Note:

For the purposes of 6A001.a.1.a.2., the acoustic sensor pressure rating determines the depth rating.

- a. Having all of the following:
 1. Designed or modified to operate at depths exceeding 300 m; and
 2. 'Sounding rate' greater than 3 800 m/s; or

Technical Note:

For the purposes of 6A001.a.1.a.2.a.2., 'sounding rate' is the product of the maximum speed (m/s) at which the sensor can operate and the maximum number of soundings per swath assuming 100% coverage. For systems that produce soundings in two directions (3D sonars), the maximum of the 'sounding rate' in either direction should be used.

- b. Survey equipment, not specified in 6A001.a.1.a.2.a., having all of the following:
 1. Designed or modified to operate at depths exceeding 100 m;
 2. Designed to take measurements at an angle exceeding 20° from the vertical;
 3. Having any of the following:
 - a. Operating frequency below 350 kHz; or
 - b. Designed to measure seabed topography at a range exceeding 200 m from the acoustic sensor; and
 4. 'Enhancement' of the depth "accuracy" through compensation of all of the following:
 - a. Motion of the acoustic sensor;
 - b. In-water propagation from sensor to the seabed and back; and
 - c. Sound speed at the sensor;

3. Side Scan Sonar (SSS) or Synthetic Aperture Sonar (SAS), designed for seabed imaging and having all of the following, and specially designed transmitting and receiving acoustic arrays therefor:
 - a. Designed or modified to operate at depths exceeding 500 m;
 - b. An 'area coverage rate' of greater than 570 m²/s while operating at the maximum range that it can operate with an 'along track resolution' of less than 15 cm; and
 - c. An 'across track resolution' of less than 15 cm;

Technical Notes:

For the purposes of 6A001.a.1.a.3.:

1. 'Area coverage rate' (m²/s) is twice the product of the sonar range (m) and the maximum speed (m/s) at which the sensor can operate at that range.
2. 'Along track resolution' (cm), for SSS only, is the product of azimuth (horizontal) beamwidth (degrees) and sonar range (m) and 0,873.
3. 'Across track resolution' (cm) is 75 divided by the signal bandwidth (kHz).

- b. Systems or transmitting and receiving arrays, designed for object detection or location, having any of the following:

N.B. *For acoustic seabed survey equipment, see 6A001.a.1.a.*

1. A transmitting frequency below 10 kHz;
2. Sound pressure level exceeding 224 dB (reference 1 µPa at 1 m) for equipment with an operating frequency in the band from 10 kHz to 24 kHz inclusive;
3. Sound pressure level exceeding 235 dB (reference 1 µPa at 1 m) for equipment with an operating frequency in the band between 24 kHz and 30 kHz;
4. Forming beams of less than 1° on any axis and having an operating frequency of less than 100 kHz;

5. Designed to operate with an unambiguous display range exceeding 5 120 m; or
6. Designed to withstand pressure during normal operation at depths exceeding 1 000 m and having transducers with any of the following:
 - a. Dynamic compensation for pressure; or
 - b. Incorporating other than lead zirconate titanate as the transduction element;
- c. Acoustic projectors (including transducers), incorporating piezoelectric, magnetostrictive, electrostrictive, electrodynamic or hydraulic elements operating individually or in a designed combination and having any of the following:

Note 1: *The control status of acoustic projectors, including transducers, specially designed for other equipment not specified in 6A001 is determined by the control status of the other equipment.*

Note 2: *6A001.a.1.c. does not control electronic sources which direct the sound vertically only, or mechanical (e.g., air gun or vapour-shock gun) or chemical (e.g., explosive) sources.*

Note 3: *Piezoelectric elements specified in 6A001.a.1.c. include those made from lead-magnesium-niobate/lead-titanate ($\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3\text{-PbTiO}_3$, or PMN-PT) single crystals grown from solid solution or lead-indium-niobate/lead-magnesium niobate/lead-titanate ($\text{Pb}(\text{In}_{1/2}\text{Nb}_{1/2})\text{O}_3\text{-Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3\text{-PbTiO}_3$, or PIN-PMN-PT) single crystals grown from solid solution.*

1. Operating at frequencies below 10 kHz and having any of the following:
 - a. Not designed for continuous operation at 100% duty cycle and having a radiated 'free-field Source Level (SL_{RMS})' exceeding $(10\log(f) + 169,77)$ dB (reference 1 μPa at 1 m) where f is the frequency in Hertz of maximum Transmitting Voltage Response (TVR) below 10kHz; or

- b. Designed for continuous operation at 100% duty cycle and having a continuously radiated 'free-field Source Level (SL_{RMS})' at 100% duty cycle exceeding $(10\log(f) + 159,77)$ dB (reference 1 μ Pa at 1 m) where f is the frequency in Hertz of maximum Transmitting Voltage Response (TVR) below 10kHz; or

Technical Note:

For the purposes of 6A001.a.1.c.1., the 'free-field Source Level (SL_{RMS})' is defined along the maximum response axis and in the far field of the acoustic projector. It can be obtained from the Transmitting Voltage Response using the following equation: $SL_{RMS} = (TVR + 20\log V_{RMS})$ dB (ref 1 μ Pa at 1 m), where SL_{RMS} is the source level, TVR is the Transmitting Voltage Response and V_{RMS} is the Driving Voltage of the Projector.

- 2. Not used;
- 3. Side-lobe suppression exceeding 22 dB;

6A001.a.1. continued

- d. Acoustic systems and equipment, designed to determine the position of surface vessels or submersible vehicles and having all the following, and specially designed components therefor:
 - 1. Detection range exceeding 1 000 m; and
 - 2. Determined position error of less than 10 m rms (root mean square) when measured at a range of 1 000 m;

Note: 6A001.a.1.d. includes:

- a. *Equipment using coherent "signal processing" between two or more beacons and the hydrophone unit carried by the surface vessel or submersible vehicle;*
- b. *Equipment capable of automatically correcting speed-of-sound propagation errors for calculation of a point.*

- e. Active individual sonars, specially designed or modified to detect, locate and automatically classify swimmers or divers, having all of the following, and specially designed transmitting and receiving acoustic arrays therefor:
 - 1. Detection range exceeding 530 m;
 - 2. Determined position error of less than 15 m rms (root mean square) when measured at a range of 530 m; and
 - 3. Transmitted pulse signal bandwidth exceeding 3 kHz;

N.B. *For diver detection systems specially designed or modified for military use, see the Military Goods Controls.*

Note: *For 6A001.a.1.e., where multiple detection ranges are specified for various environments, the greatest detection range is used.*

6A001.a. continued

2. Passive systems, equipment and specially designed components therefor, as follows:

Note: 6A001.a.2. also controls receiving equipment, whether or not related in normal application to separate active equipment, and specially designed components therefor.

- a. Hydrophones having any of the following:

Note: The control status of hydrophones specially designed for other equipment is determined by the control status of the other equipment.

Technical Notes:

For the purposes of 6A001.a.2.a.:

1. *Hydrophones consist of one or more sensing elements producing a single acoustic output channel. Those that contain multiple elements can be referred to as a hydrophone group.*
2. *Underwater acoustic transducers designed to operate as passive receivers are hydrophones.*
1. Incorporating continuous flexible sensing elements;
2. Incorporating flexible assemblies of discrete sensing elements with either a diameter or length less than 20 mm and with a separation between elements of less than 20 mm;
3. Having any of the following sensing elements:
 - a. Optical fibres;
 - b. 'Piezoelectric polymer films' other than polyvinylidene-fluoride (PVDF) and its co-polymers {P(VDF-TrFE) and P(VDF-TFE)};
 - c. 'Flexible piezoelectric composites';
 - d. Lead-magnesium-niobate/lead-titanate (i.e., $\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3\text{-PbTiO}_3$, or PMN-PT) piezoelectric single crystals grown from solid solution; or
 - e. Lead-indium-niobate/lead-magnesium niobate/lead-titanate (i.e., $\text{Pb}(\text{In}_{1/2}\text{Nb}_{1/2})\text{O}_3\text{-Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3\text{-PbTiO}_3$, or PIN-PMN-PT) piezoelectric single crystals grown from solid solution;

6A001.a.2.a. continued

4. A 'hydrophone sensitivity' greater (better) than -180 dB at any depth with no acceleration compensation;
5. Designed to operate at depths exceeding 35 m with acceleration compensation; or
6. Designed for operation at depths exceeding 1 000 m and having a 'hydrophone sensitivity' greater (better) than -230 dB below 4 kHz;