

Technical Notes:

1. *For the purposes of 6A001.a.2.a.3.b., 'piezoelectric polymer film' sensing elements consist of polarised polymer film that is stretched over and attached to a supporting frame or spool (mandrel).*
2. *For the purposes of 6A001.a.2.a.3.c., 'flexible piezoelectric composite' sensing elements consist of piezoelectric ceramic particles or fibres combined with an electrically insulating, acoustically transparent rubber, polymer or epoxy compound, where the compound is an integral part of the sensing elements.*
3. *For the purposes of 6A001.a.2.a., 'hydrophone sensitivity' is defined as twenty times the logarithm to the base 10 of the ratio of rms output voltage to a 1 V rms reference, when the hydrophone sensor, without a pre-amplifier, is placed in a plane wave acoustic field with an rms pressure of 1 μ Pa. For example, a hydrophone of -160 dB (reference 1 V per μ Pa) would yield an output voltage of 10^{-8} V in such a field, while one of -180 dB sensitivity would yield only 10^{-9} V output. Thus, -160 dB is better than -180 dB.*

6A001.a.2. continued

- b. Towed acoustic hydrophone arrays having any of the following:

Technical Note:

For the purposes of 6A001.a.2.b., hydrophone arrays consist of a number of hydrophones providing multiple acoustic output channels.

1. Hydrophone group spacing of less than 12,5 m or 'able to be modified' to have hydrophone group spacing of less than 12,5 m;
2. Designed or 'able to be modified' to operate at depths exceeding 35 m;
3. Heading sensors specified in 6A001.a.2.d.;
4. Longitudinally reinforced array hoses;
5. An assembled array of less than 40 mm in diameter;
6. Not used;
7. Hydrophone characteristics specified in 6A001.a.2.a.; or
8. Accelerometer-based hydro-acoustic sensors specified in 6A001.a.2.g.;

Technical Note:

For the purposes of 6A001.a.2.b., 'able to be modified' means having provisions to allow a change of the wiring or interconnections to alter hydrophone group spacing or operating depth limits. These provisions are: spare wiring exceeding 10% of the number of wires, hydrophone group spacing adjustment blocks or internal depth limiting devices that are adjustable or that control more than one hydrophone group.

6A001.a.2. continued

- c. Processing equipment, specially designed for towed acoustic hydrophone arrays, having "user-accessible programmability" and time or frequency domain processing and correlation, including spectral analysis, digital filtering and beamforming using Fast Fourier or other transforms or processes;
- d. Heading sensors having all of the following:
 - 1. An "accuracy" of less (better) than 0,5°; and
 - 2. Designed to operate at depths exceeding 35 m or having an adjustable or removable depth sensing device in order to operate at depths exceeding 35 m;

N.B. For inertial heading systems, see 7A003.c.
- e. Bottom or bay-cable hydrophone arrays, having any of the following:
 - 1. Incorporating hydrophones specified in 6A001.a.2.a.;
 - 2. Incorporating multiplexed hydrophone group signal modules having all of the following characteristics:
 - a. Designed to operate at depths exceeding 35 m or having an adjustable or removable depth sensing device in order to operate at depths exceeding 35 m; and
 - b. Capable of being operationally interchanged with towed acoustic hydrophone array modules; or
 - 3. Incorporating accelerometer-based hydro-acoustic sensors specified in 6A001.a.2.g.;
- f. Processing equipment, specially designed for bottom or bay cable systems, having "user-accessible programmability" and time or frequency domain processing and correlation, including spectral analysis, digital filtering and beamforming using Fast Fourier or other transforms or processes;

6A001.a.2. continued

- g. Accelerometer-based hydro-acoustic sensors having all of the following:
 - 1. Composed of three accelerometers arranged along three distinct axes;
 - 2. Having an overall 'acceleration sensitivity' greater (better) than 48 dB (reference 1 000 mV rms per 1g);
 - 3. Designed to operate at depths greater than 35 meters; and
 - 4. Operating frequency below 20 kHz.

Note: 6A001.a.2.g. does not control particle velocity sensors or geophones.

Technical Notes:

- 1. For the purposes of 6A001.a.2.g., accelerometer-based hydro-acoustic sensors are also known as vector sensors.
 - 2. For the purposes of 6A001.a.2.g.2., 'acceleration sensitivity' is defined as twenty times the logarithm to the base 10 of the ratio of rms output voltage to a 1 V rms reference, when the hydro-acoustic sensor, without a preamplifier, is placed in a plane wave acoustic field with an rms acceleration of 1 g (i.e., 9,81 m/s²).
- b. Correlation-velocity and Doppler-velocity sonar log equipment, designed to measure the horizontal speed of the equipment carrier relative to the seabed, as follows:

6A001.b. continued

1. Correlation-velocity sonar log equipment having any of the following characteristics:
 - a. Designed to operate at distances between the carrier and the seabed exceeding 500 m; or
 - b. Having speed "accuracy" less (better) than 1% of speed;
2. Doppler-velocity sonar log equipment having speed "accuracy" less (better) than 1% of speed.

Note 1: 6A001.b. does not control depth sounders limited to any of the following:

- a. Measuring the depth of water;
- b. Measuring the distance of submerged or buried objects; or
- c. Fish finding.

Note 2: 6A001.b. does not control equipment specially designed for installation on surface vessels.

- c. Not used.

6A002 Optical sensors or equipment and components therefor, as follows:

N.B. SEE ALSO 6A102.

a. Optical detectors as follows:

1. "Space-qualified" solid-state detectors as follows:

Note: For the purpose of 6A002.a.1., solid-state detectors include "focal plane arrays".

a. "Space-qualified" solid-state detectors having all of the following:

1. A peak response in the wavelength range exceeding 10 nm but not exceeding 300 nm; and
2. A response of less than 0,1% relative to the peak response at a wavelength exceeding 400 nm;

b. "Space-qualified" solid-state detectors having all of the following:

1. A peak response in the wavelength range exceeding 900 nm but not exceeding 1 200 nm; and
2. A response "time constant" of 95 ns or less;

c. "Space-qualified" solid-state detectors having a peak response in the wavelength range exceeding 1 200 nm but not exceeding 30 000 nm;

d. "Space-qualified" "focal plane arrays" having more than 2 048 elements per array and having a peak response in the wavelength range exceeding 300 nm but not exceeding 900 nm;

6A002.a. continued

2. Image intensifier tubes and specially designed components therefor, as follows:

Note: 6A002.a.2. does not control non-imaging photomultiplier tubes having an electron sensing device in the vacuum space limited solely to any of the following:

- a. A single metal anode; or*
 - b. Metal anodes with a centre to centre spacing greater than 500 μm .*
- a. Image intensifier tubes having all of the following:
 1. A peak response in the wavelength range exceeding 400 nm but not exceeding 1 050 nm;
 2. Electron image amplification using any of the following:
 - a. A microchannel plate with a hole pitch (centre-to-centre spacing) of 12 μm or less; or
 - b. An electron sensing device with a non-binned pixel pitch of 500 μm or less, specially designed or modified to achieve "charge multiplication" other than by a microchannel plate; and
 3. Any of the following photocathodes:
 - a. Multialkali photocathodes (e.g., S-20 and S-25) having a luminous sensitivity exceeding 350 $\mu\text{A/lm}$;
 - b. GaAs or GaInAs photocathodes; or
 - c. Other "III/V compound" semiconductor photocathodes having a maximum "radiant sensitivity" exceeding 10 mA/W;

6A002.a.2. continued

- b. Image intensifier tubes having all of the following:
 - 1. A peak response in the wavelength range exceeding 1 050 nm but not exceeding 1 800 nm;
 - 2. Electron image amplification using any of the following:
 - a. A microchannel plate with a hole pitch (centre-to-centre spacing) of 12 μm or less; or
 - b. An electron sensing device with a non-binned pixel pitch of 500 μm or less, specially designed or modified to achieve "charge multiplication" other than by a microchannel plate; and
 - 3. "III/V compound" semiconductor (e.g., GaAs or GaInAs) photocathodes and transferred electron photocathodes, having a maximum "radiant sensitivity" exceeding 15 mA/W;
- c. Specially designed components as follows:
 - 1. Microchannel plates having a hole pitch (centre-to-centre spacing) of 12 μm or less;
 - 2. An electron sensing device with a non-binned pixel pitch of 500 μm or less, specially designed or modified to achieve "charge multiplication" other than by a microchannel plate;
 - 3. "III/V compound" semiconductor (e.g., GaAs or GaInAs) photocathodes and transferred electron photocathodes;

Note: 6A002.a.2.c.3. does not control compound semiconductor photocathodes designed to achieve a maximum "radiant sensitivity" of any of the following:

- a. 10 mA/W or less at the peak response in the wavelength range exceeding 400 nm but not exceeding 1 050 nm; or
- b. 15 mA/W or less at the peak response in the wavelength range exceeding 1 050 nm but not exceeding 1 800 nm.

6A002.a. continued

3. Non-"space-qualified" "focal plane arrays" as follows:

N.B. 'Microbolometer' non-"space-qualified" "focal plane arrays" are only specified in 6A002.a.3.f.

Technical Note:

For the purposes of 6A002.a.3., linear or two-dimensional multi-element detector arrays are referred to as "focal plane arrays".

Note 1: 6A002.a.3. includes photoconductive arrays and photovoltaic arrays.

Note 2: 6A002.a.3. does not control:

- a. Multi-element (not to exceed 16 elements) encapsulated photoconductive cells using either lead sulphide or lead selenide;
- b. Pyroelectric detectors using any of the following:
 1. Triglycine sulphate and variants;
 2. Lead-lanthanum-zirconium titanate and variants;
 3. Lithium tantalate;
 4. Polyvinylidene fluoride and variants; or
 5. Strontium barium niobate and variants;
- c. "Focal plane arrays" specially designed or modified to achieve "charge multiplication" and limited by design to have a maximum "radiant sensitivity" of 10 mA/W or less for wavelengths exceeding 760 nm, having all of the following:
 1. Incorporating a response limiting mechanism designed not to be removed or modified; and
 2. Any of the following:
 - a. The response limiting mechanism is integral to or combined with the detector element; or
 - b. The "focal plane array" is only operable with the response limiting mechanism in place;

Technical Note:

For the purposes of 6A002.a.3. Note 2.c.2.a., a response limiting mechanism integral to the detector element is designed not to be removed or modified without rendering the detector inoperable.

- d. Thermopile arrays having less than 5 130 elements.

6A002.a.3. continued

- a. Non-"space-qualified" "focal plane arrays" having all of the following:
 - 1. Individual elements with a peak response within the wavelength range exceeding 900 nm but not exceeding 1 050 nm; and
 - 2. Any of the following:
 - a. A response "time constant" of less than 0,5 ns; or
 - b. Specially designed or modified to achieve "charge multiplication" and having a maximum "radiant sensitivity" exceeding 10 mA/W;
- b. Non-"space-qualified" "focal plane arrays" having all of the following:
 - 1. Individual elements with a peak response in the wavelength range exceeding 1 050 nm but not exceeding 1 200 nm; and
 - 2. Any of the following:
 - a. A response "time constant" of 95 ns or less; or
 - b. Specially designed or modified to achieve "charge multiplication" and having a maximum "radiant sensitivity" exceeding 10 mA/W;
- c. Non-"space-qualified" non-linear (2-dimensional) "focal plane arrays" having individual elements with a peak response in the wavelength range exceeding 1 200 nm but not exceeding 30 000 nm;

N.B. Silicon and other material based 'microbolometer' non-"space-qualified" "focal plane arrays" are only specified in 6A002.a.3.f.

6A002.a.3. continued

- d. Non-"space-qualified" linear (1-dimensional) "focal plane arrays" having all of the following:
 - 1. Individual elements with a peak response in the wavelength range exceeding 1 200 nm but not exceeding 3 000 nm; and
 - 2. Any of the following:
 - a. A ratio of 'scan direction' dimension of the detector element to the 'cross-scan direction' dimension of the detector element of less than 3,8; or
 - b. Signal processing in the detector elements;

Note: 6A002.a.3.d. does not control "focal plane arrays" with 32 elements or fewer, where all the detector elements are made from germanium.

Technical Notes:

For the purposes of 6A002.a.3.d.2.a:

- 1. 'Scan direction' is defined as the axis perpendicular to the linear array of detector elements.*
- 2. 'Cross-scan direction' is defined as the axis parallel to the linear array of detector elements.*

- e. Non-"space-qualified" linear (1-dimensional) "focal plane arrays" having individual elements with a peak response in the wavelength range exceeding 3 000 nm but not exceeding 30 000 nm;
- f. Non-"space-qualified" non-linear (2-dimensional) infrared "focal plane arrays" based on 'microbolometer' material having individual elements with an unfiltered response in the wavelength range equal to or exceeding 8 000 nm but not exceeding 14 000 nm;

Technical Note:

For the purposes of 6A002.a.3.f., 'microbolometer' is defined as a thermal imaging detector that, as a result of a temperature change in the detector caused by the absorption of infrared radiation, is used to generate any usable signal.

6A002.a.3. continued

- g. Non-"space-qualified" "focal plane arrays" having all of the following:
 - 1. Individual detector elements with a peak response in the wavelength range exceeding 400 nm but not exceeding 900 nm;
 - 2. Specially designed or modified to achieve "charge multiplication" and having a maximum "radiant sensitivity" exceeding 10 mA/W for wavelengths exceeding 760 nm; and
 - 3. Greater than 32 elements;
- b. "Monospectral imaging sensors" and "multispectral imaging sensors", designed for remote sensing applications and having any of the following:
 - 1. An Instantaneous Field of View (IFOV) of less than 200 μ rad (microradians); or
 - 2. Specified for operation in the wavelength range exceeding 400 nm but not exceeding 30 000 nm and having all the following:
 - a. Providing output imaging data in digital format; and
 - b. Having any of the following characteristics:
 - 1. "Space-qualified"; or
 - 2. Designed for airborne operation, using other than silicon detectors, and having an IFOV of less than 2,5 mrad (milliradians);

Note: 6A002.b.1. does not control "monospectral imaging sensors" with a peak response in the wavelength range exceeding 300 nm but not exceeding 900 nm and only incorporating any of the following non-"space-qualified" detectors or non-"space-qualified" "focal plane arrays":

- 1. *Charge Coupled Devices (CCD) not designed or modified to achieve "charge multiplication"; or*
- 2. *Complementary Metal Oxide Semiconductor (CMOS) devices not designed or modified to achieve "charge multiplication".*

6A002 continued

- c. 'Direct view' imaging equipment incorporating any of the following:
 - 1. Image intensifier tubes specified in 6A002.a.2.a. or 6A002.a.2.b.;
 - 2. "Focal plane arrays" specified in 6A002.a.3.; or
 - 3. Solid-state detectors specified in 6A002.a.1.;

Technical Note:

For the purposes of 6A002.c., 'direct view' refers to imaging equipment that presents a visual image to a human observer without converting the image into an electronic signal for television display, and that cannot record or store the image photographically, electronically or by any other means.

Note: 6A002.c. does not control equipment as follows, when incorporating other than GaAs or GaInAs photocathodes:

- a. Industrial or civilian intrusion alarm, traffic or industrial movement control or counting systems;
- b. Medical equipment;
- c. Industrial equipment used for inspection, sorting or analysis of the properties of materials;
- d. Flame detectors for industrial furnaces;
- e. Equipment specially designed for laboratory use.

- d. Special support components for optical sensors, as follows:
 - 1. "Space-qualified" cryocoolers;
 - 2. Non-"space-qualified" cryocoolers having a cooling source temperature below 218 K (-55°C), as follows:
 - a. Closed cycle type with a specified Mean-Time-To-Failure (MTTF) or Mean-Time-Between-Failures (MTBF), exceeding 2 500 hours;
 - b. Joule-Thomson (JT) self-regulating minicoolers having bore (outside) diameters of less than 8 mm;
 - 3. Optical sensing fibres specially fabricated either compositionally or structurally, or modified by coating, to be acoustically, thermally, inertially, electromagnetically or nuclear radiation sensitive;

Note 1: 6A002.d.3. does not control encapsulated optical sensing fibres specially designed for bore hole sensing applications.

Note 2: 6A002.d.3. does not control optical fibre Bragg gratings specially designed for thermal sensing, having a maximum sensing temperature less than 423 K (150°C) and a minimum sensing temperature greater than 173 K (-100°C).

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- e. Not used.
- f. 'Read-Out Integrated Circuits' ('ROIC') specially designed for "focal plane arrays" specified in 6A002.a.3.

Note: 6A002.f. does not control 'Read-Out Integrated Circuit' ('ROIC') specially designed for civil automotive applications.

Technical Note:

For the purposes of 6A002.f., a 'Read-Out Integrated Circuit' ('ROIC') is an integrated circuit designed to underlie or be bonded to a "focal plane array" and used to read-out (i.e., extract and register) signals produced by the detector elements. At a minimum the 'ROIC' reads the charge from the detector elements by extracting the charge and applying a multiplexing function in a manner that retains the relative spatial position and orientation information of the detector elements for processing inside or outside the 'ROIC'.

6A003 Cameras, systems or equipment, and components therefor, as follows:

N.B. SEE ALSO 6A203.

- a. Instrumentation cameras and specially designed components therefor, as follows:

Note: *Instrumentation cameras, specified in 6A003.a.3. to 6A003.a.5., with modular structures should be evaluated by their maximum capability, using plug-ins available according to the camera manufacturer's specifications.*

- 1. Not used;
- 2. Not used;
- 3. Electronic streak cameras having temporal resolution less (better) than 50 ns;
- 4. Electronic framing cameras having a speed exceeding 1 000 000 frames/s;
- 5. Electronic cameras having all of the following:
 - a. An electronic shutter speed (gating capability) of less than 1 μ s per full frame; and
 - b. A read out time allowing a framing rate of more than 125 full frames per second;

6A003.a. continued

6. Plug-ins having all of the following characteristics:
 - a. Specially designed for instrumentation cameras which have modular structures and which are specified in 6A003.a.; and
 - b. Enabling these cameras to meet the characteristics specified in 6A003.a.3., 6A003.a.4., or 6A003.a.5., according to the manufacturer's specifications;
- b. Imaging cameras as follows:

Note: 6A003.b. does not control television or video cameras, specially designed for television broadcasting.

 1. Video cameras incorporating solid-state sensors, having a peak response in the wavelength range exceeding 10 nm but not exceeding 30 000 nm and having all of the following:
 - a. Having any of the following:
 1. More than 4×10^6 "active pixels" per solid-state array for monochrome (black and white) cameras;
 2. More than 4×10^6 "active pixels" per solid-state array for colour cameras incorporating three solid-state arrays; or
 3. More than 12×10^6 "active pixels" for solid-state array colour cameras incorporating one solid-state array; and
 - b. Having any of the following:
 1. Optical mirrors specified in 6A004.a.;
 2. Optical control equipment specified in 6A004.d.; or
 3. The capability for annotating internally generated 'camera tracking data';

Technical Notes:

1. *For the purposes of 6A003.b.1., digital video cameras should be evaluated by the maximum number of "active pixels" used for capturing moving images.*
2. *For the purposes of 6A003.b.1.b.3., 'camera tracking data' is the information necessary to define camera line of sight orientation with respect to the earth. This includes: 1) the horizontal angle the camera line of sight makes with respect to the earth's magnetic field direction and; 2) the vertical angle between the camera line of sight and the earth's horizon.*

6A003.b. continued

2. Scanning cameras and scanning camera systems, having all of the following:
 - a. A peak response in the wavelength range exceeding 10 nm but not exceeding 30 000 nm;
 - b. Linear detector arrays with more than 8 192 elements per array; and
 - c. Mechanical scanning in one direction;

Note: 6A003.b.2. does not control scanning cameras and scanning camera systems, specially designed for any of the following:

- a. Industrial or civilian photocopiers;*
 - b. Image scanners specially designed for civil, stationary, close proximity scanning applications (e.g., reproduction of images or print contained in documents, artwork or photographs); or*
 - c. Medical equipment.*
3. Imaging cameras incorporating image intensifier tubes specified in 6A002.a.2.a. or 6A002.a.2.b.;
 4. Imaging cameras, not specified in 6A002.b., incorporating "focal plane arrays" having any of the following:
 - a. Incorporating "focal plane arrays" specified in 6A002.a.3.a. to 6A002.a.3.e.;
 - b. Incorporating "focal plane arrays" specified in 6A002.a.3.f.; or
 - c. Incorporating "focal plane arrays" specified in 6A002.a.3.g.;

Note 1: Imaging cameras specified in 6A003.b.4. include "focal plane arrays" combined with sufficient "signal processing" electronics, beyond the read out integrated circuit, to enable as a minimum the output of an analogue or digital signal once power is supplied.

- Note 2: 6A003.b.4.a. does not control imaging cameras incorporating linear "focal plane arrays" with 12 elements or fewer, not employing time-delay-and-integration within the element and designed for any of the following:
- a. Industrial or civilian intrusion alarm, traffic or industrial movement control or counting systems;
 - b. Industrial equipment used for inspection or monitoring of heat flows in buildings, equipment or industrial processes;
 - c. Industrial equipment used for inspection, sorting or analysis of the properties of materials;
 - d. Equipment specially designed for laboratory use; or
 - e. Medical equipment.

- Note 3: 6A003.b.4.b. does not control imaging cameras having any of the following:
- a. A maximum frame rate equal to or less than 9 Hz ;
 - b. Having all of the following:
 1. Having a minimum horizontal or vertical 'Instantaneous Field of View (IFOV)' of at least 2 mrad (milliradians);

Technical Note:

For the purposes of 6A003.b.4. Note 3.b.1., 'Instantaneous Field of View (IFOV)' is the lesser figure of the 'Horizontal IFOV' or the 'Vertical IFOV'.

'Horizontal IFOV' = horizontal Field of View (FOV)/number of horizontal detector elements

'Vertical IFOV' = vertical Field of View (FOV)/number of vertical detector elements.

2. Incorporating a fixed focal-length lens that is not designed to be removed;
3. Not incorporating a 'direct view' display, and
4. Having any of the following:
 - a. No facility to obtain a viewable image of the detected Field of View, or
 - b. The camera is designed for a single kind of application and designed not to be user modified; or
- c. The camera is specially designed for installation into a civilian passenger land vehicle and having all of the following:
 1. The placement and configuration of the camera within the vehicle are solely to assist the driver in the safe operation of the vehicle;
 2. Is only operable when installed in any of the following:
 - a. The civilian passenger land vehicle for which it was intended and the vehicle

- weighs less than 4 500 kg (gross vehicle weight); or*
- b. A specially designed, authorised maintenance test facility; and*
- 3. Incorporates an active mechanism that forces the camera not to function when it is removed from the vehicle for which it was intended.*

Note 4: 6A003.b.4.c. does not control imaging cameras having any of the following:

- a. Having all of the following:
 1. Where the camera is specially designed for installation as an integrated component into indoor and wall-plug-operated systems or equipment, limited by design for a single kind of application, as follows;
 - a. Industrial process monitoring, quality control, or analysis of the properties of materials;
 - b. Laboratory equipment specially designed for scientific research;
 - c. Medical equipment;
 - d. Financial fraud detection equipment;
 2. Is only operable when installed in any of the following:
 - a. The system(s) or equipment for which it was intended; or
 - b. A specially designed, authorised maintenance facility; and
 3. Incorporates an active mechanism that forces the camera not to function when it is removed from the system(s) or equipment for which it was intended;

- b. Where the camera is specially designed for installation into a civilian passenger land vehicle or passenger and vehicle ferries, and having all of the following:*
 - 1. The placement and configuration of the camera within the vehicle or ferry is solely to assist the driver or operator in the safe operation of the vehicle or ferry;*
 - 2. Is only operable when installed in any of the following:*
 - a. The civilian passenger land vehicle for which it was intended and the vehicle weighs less than 4 500 kg (gross vehicle weight);*
 - b. The passenger and vehicle ferry for which it was intended and having a Length Overall (LOA) 65 m or greater; or*
 - c. A specially designed, authorised maintenance test facility; and*
 - 3. Incorporates an active mechanism that forces the camera not to function when it is removed from the vehicle for which it was intended;*
- c. Limited by design to have a maximum "radiant sensitivity" of 10 mA/W or less for wavelengths exceeding 760 nm, having all of the following:*
 - 1. Incorporating a response limiting mechanism designed not to be removed or modified;*
 - 2. Incorporates an active mechanism that forces the camera not to function when the response limiting mechanism is removed; and*
 - 3. Not specially designed or modified for underwater use: or*

6A003.b.4 Note 4 continued

- d. *Having all of the following:*
 - 1. *Not incorporating a 'direct view' or electronic image display;*
 - 2. *Has no facility to output a viewable image of the detected field of view;*
 - 3. *The "focal plane array" is only operable when installed in the camera for which it was intended; and*
 - 4. *The "focal plane array" incorporates an active mechanism that forces it to be permanently inoperable when removed from the camera for which it was intended.*

Technical Note:

For the purposes of 6A003.b.4., 'direct view' refers to an imaging camera operating in the infrared spectrum that presents a visual image to a human observer using a near-to-eye micro display incorporating any light-security mechanism.

- 5. Imaging cameras incorporating solid-state detectors specified in 6A002.a.1.

6A004 Optical equipment and components, as follows:

- a. Optical mirrors (reflectors) as follows:

Technical Note:

For the purposes of 6A004.a., Laser Induced Damage Threshold (LIDT) is measured according to ISO 21254-1:2011.

N.B. *For optical mirrors specially designed for lithography equipment, see 3B001.*

- 1. 'Deformable mirrors' having an active optical aperture greater than 10 mm and having any of the following, and specially designed components therefor,
 - a. Having all the following:
 - 1. A mechanical resonant frequency of 750 Hz or more; and
 - 2. More than 200 actuators; or
 - b. A Laser Induced Damage Threshold (LIDT) being any of the following:
 - 1. Greater than 1 kW/ cm² using a "Continuous Wave (CW) laser"; or
 - 2. Greater than 2 J/ cm² using 20 ns "laser" pulses at 20 Hz repetition rate;

Technical Notes:

For the purposes of 6A004.a.1.:

'Deformable mirrors' are mirrors having any of the following:

1.
 - a. *A single continuous optical reflecting surface which is dynamically deformed by the application of individual torques or forces to compensate for distortions in the optical waveform incident upon the mirror; or*
 - b. *Multiple optical reflecting elements that can be individually and dynamically repositioned by the application of torques or forces to compensate for distortions in the optical waveform incident upon the mirror.*
2. *'Deformable mirrors' are also known as adaptive optic mirrors.*
2. *Lightweight monolithic mirrors having an average "equivalent density" of less than 30 kg/m² and a total mass exceeding 10 kg;*

Note: *6A004.a.2. does not control mirrors specially designed to direct solar radiation for terrestrial heliostat installations.*

6A004.a. continued

3. Lightweight "composite" or foam mirror structures having an average "equivalent density" of less than 30 kg/m^2 and a total mass exceeding 2 kg;

Note: 6A004.a.3. does not control mirrors specially designed to direct solar radiation for terrestrial heliostat installations.

4. Mirrors specially designed for beam steering mirror stages specified in 6A004.d.2.a. with a flatness of $\lambda/10$ or better (λ is equal to 633 nm) and having any of the following:
 - a. Diameter or major axis length greater than or equal to 100 mm; or
 - b. Having all of the following:
 1. Diameter or major axis length greater than 50 mm but less than 100 mm; and
 2. A Laser Induced Damage Threshold (LIDT) being any of the following:
 - a. Greater than 10 kW/cm^2 using a "CW laser"; or
 - b. Greater than 20 J/cm^2 using 20 ns "laser" pulses at 20 Hz repetition rate;
- b. Optical components made from zinc selenide (ZnSe) or zinc sulphide (ZnS) with transmission in the wavelength range exceeding 3 000 nm but not exceeding 25 000 nm and having any of the following:
 1. Exceeding 100 cm^3 in volume; or
 2. Exceeding 80 mm in diameter or length of major axis and 20 mm in thickness (depth);
- c. "Space-qualified" components for optical systems, as follows:
 1. Components lightweighted to less than 20% "equivalent density" compared with a solid blank of the same aperture and thickness;
 2. Raw substrates, processed substrates having surface coatings (single-layer or multi-layer, metallic or dielectric, conducting, semiconducting or insulating) or having protective films;
 3. Segments or assemblies of mirrors designed to be assembled in space into an optical system with a collecting aperture equivalent to or larger than a single optic 1 m in diameter;

6A004.c. continued

4. Components manufactured from "composite" materials having a coefficient of linear thermal expansion, in any coordinate direction, equal to or less than $5 \times 10^{-6}/K$;
- d. Optical control equipment as follows:
 1. Equipment specially designed to maintain the surface figure or orientation of the "space-qualified" components specified in 6A004.c.1. or 6A004.c.3.;
 2. Steering, tracking, stabilisation and resonator alignment equipment as follows:
 - a. Beam steering mirror stages designed to carry mirrors having diameter or major axis length greater than 50 mm and having all of the following, and specially designed electronic control equipment therefor:
 1. A maximum angular travel of ± 26 mrad or more;
 2. A mechanical resonant frequency of 500 Hz or more; and
 3. An angular "accuracy" of 10 μ rad (microradians) or less (better);
 - b. Resonator alignment equipment having bandwidths equal to or more than 100 Hz and an "accuracy" of 10 μ rad or less (better);
 3. Gimbals having all of the following:
 - a. A maximum slew exceeding 5° ;
 - b. A bandwidth of 100 Hz or more;
 - c. Angular pointing errors of 200 μ rad (microradians) or less; and
 - d. Having any of the following:
 1. Exceeding 0,15 m but not exceeding 1 m in diameter or major axis length and capable of angular accelerations exceeding 2 rad (radians)/s²; or
 2. Exceeding 1 m in diameter or major axis length and capable of angular accelerations exceeding 0,5 rad (radians)/s²;

6A004.d. continued

4. Not used;
- e. 'Aspheric optical elements' having all of the following:
 1. Largest dimension of the optical-aperture greater than 400 mm;
 2. Surface roughness less than 1 nm (rms) for sampling lengths equal to or greater than 1 mm; and
 3. Coefficient of linear thermal expansion's absolute magnitude less than $3 \times 10^{-6}/K$ at 25°C.

Technical Notes:

1. *For the purposes of 6A004.e., an 'aspheric optical element' is any element used in an optical system whose imaging surface or surfaces are designed to depart from the shape of an ideal sphere.*
2. *For the purposes of 6A004.e.2., manufacturers are not required to measure the surface roughness unless the optical element was designed or manufactured with the intent to meet, or exceed, the control parameter.*

Note 6A004.e. does not control 'aspheric optical elements' having any of the following:

- a. *Largest optical-aperture dimension less than 1 m and focal length to aperture ratio equal to or greater than 4,5:1;*
- b. *Largest optical-aperture dimension equal to or greater than 1 m and focal length to aperture ratio equal to or greater than 7:1;*
- c. *Designed as Fresnel, flyeye, stripe, prism or diffractive optical elements;*
- d. *Fabricated from borosilicate glass having a coefficient of linear thermal expansion greater than $2,5 \times 10^{-6}/K$ at 25°C; or*
- e. *An X-ray optical element having inner mirror capabilities (e.g., tube-type mirrors).*

N.B. *For 'aspheric optical elements' specially designed for lithography equipment, see 3B001.*

6A004. continued

- f. Dynamic wavefront measuring equipment having all of the following:
 - 1. 'Frame rates' equal to or more than 1 kHz; and
 - 2. A wavefront accuracy equal to or less (better) than $\lambda/20$ at the designed wavelength.

Technical Note:

For the purposes of 6A004.f., 'frame rate' is a frequency at which all "active pixels" in the "focal plane array" are integrated for recording images projected by the wavefront sensor optics.

6A005 "Lasers", other than those specified in 0B001.g.5. or 0B001.h.6., components and optical equipment, as follows:

N.B. SEE ALSO 6A205.

Note 1: Pulsed "lasers" include those that run in a Continuous Wave (CW) mode with pulses superimposed.

Note 2: Excimer, semiconductor, chemical, CO, CO₂, and "non-repetitive pulsed" Nd:glass "lasers" are only specified in 6A005.d.

Note 3: 6A005 includes fibre "lasers".

Note 4: The control status of "lasers" incorporating frequency conversion (i.e., wavelength change) by means other than one "laser" pumping another "laser" is determined by applying the control parameters for both the output of the source "laser" and the frequency-converted optical output.

Note 5: 6A005 does not control "lasers" as follows:

- a. Ruby with output energy below 20 J;
- b. Nitrogen;
- c. Krypton.

Technical Note:

For the purposes of 6A005.a. and 6A005.b., 'single transverse mode' refers to "lasers" with a beam profile having an M^2 -factor of less than 1,3, while 'multiple transverse mode' refers to "lasers" with a beam profile having an M^2 -factor equal to or greater than 1,3.

6A005 continued

- a. Non-"tunable" "Continuous Wave (CW) lasers" having any of the following:
 - 1. Output wavelength less than 150 nm and output power exceeding 1 W;
 - 2. Output wavelength of 150 nm or more but not exceeding 510 nm and output power exceeding 30 W;
Note: 6A005.a.2. does not control Argon "lasers" having an output power equal to or less than 50 W.
 - 3. Output wavelength exceeding 510 nm but not exceeding 540 nm and any of the following:
 - a. 'Single transverse mode' output and output power exceeding 50 W;
or
 - b. 'Multiple transverse mode' output and output power exceeding 150 W;
 - 4. Output wavelength exceeding 540 nm but not exceeding 800 nm and output power exceeding 30 W;
 - 5. Output wavelength exceeding 800 nm but not exceeding 975 nm and any of the following:
 - a. 'Single transverse mode' output and output power exceeding 50 W;
or
 - b. 'Multiple transverse mode' output and output power exceeding 80 W;

6A005.a. continued

6. Output wavelength exceeding 975 nm but not exceeding 1 150 nm and any of the following:
 - a. 'Single transverse mode' output and any of the following:
 1. Output power exceeding 2 kW; or
 2. Having all of the following:
 - a. Output power exceeding 500 W; and
 - b. Spectral bandwidth less than 40 GHz; or
 3. Having all of the following:
 - a. Output power exceeding 1,5 kW; and
 - b. Spectral bandwidth greater than or equal to 40 GHz and less than 100 GHz; or
 - b. 'Multiple transverse mode' output and any of the following:
 1. Not used
 2. Output power exceeding 3 kW;

Note 1: 6A005.a.6.b. does not control 'multiple transverse mode', industrial "lasers" with output power exceeding 3 kW and not exceeding 6 kW with a total mass greater than 1 200 kg. For the purposes of this Note, total mass includes all components required to operate the "laser", e.g., "laser", power supply, heat exchanger, but excludes external optics for beam conditioning or delivery.

- Note 2: 6A005.a.6.b. does not control 'multiple transverse mode', industrial "lasers" having any of the following:
- a. Not used;
 - b. Not used;
 - c. Not used;
 - d. Not used;
 - e. Output power exceeding 3 kW but not exceeding 12 kW and having a Beam Parameter Product (BPP) exceeding 3,2 mm•mrad;
 - f. Not used;
 - g. Not used;
 - h. Output power exceeding 12 kW but not exceeding 20 kW and having a BPP exceeding 3,9 mm•mrad; or
 - i. Output power exceeding 20 kW but not exceeding 40 kW and having a BPP exceeding 5 mm•mrad.

6A005.a. continued

7. Output wavelength exceeding 1 150 nm but not exceeding 1 555 nm and any of the following:
 - a. 'Single transverse mode' and output power exceeding 50 W; or
 - b. 'Multiple transverse mode' and output power exceeding 80 W;
 8. Output wavelength exceeding 1 555 nm but not exceeding 1 850 nm and output power exceeding 1 W;
 9. Output wavelength exceeding 1 850 nm but not exceeding 2 100 nm, and any of the following:
 - a. 'Single transverse mode' and output power exceeding 1 W; or
 - b. 'Multiple transverse mode' output and output power exceeding 120 W; or
 10. Output wavelength exceeding 2 100 nm and output power exceeding 1 W;
- b. Non-"tunable" 'pulsed lasers' having any of the following:

Technical Note:

For the purposes of 6A005.b., a 'pulsed laser' is a "laser" having a "pulse duration" that is less than or equal to 0,25 seconds.

1. Output wavelength less than 150 nm and any of the following:
 - a. Output energy exceeding 50 mJ per pulse and "peak power" exceeding 1 W; or
 - b. "Average output power" exceeding 1 W;
2. Output wavelength of 150 nm or more but not exceeding 510 nm and any of the following:
 - a. Output energy exceeding 1,5 J per pulse and "peak power" exceeding 30 W; or
 - b. "Average output power" exceeding 30 W;

Note: 6A005.b.2.b. does not control Argon "lasers" having an "average output power" equal to or less than 50 W.

6A005.b. continued

3. Output wavelength exceeding 510 nm but not exceeding 540 nm and any of the following:
 - a. 'Single transverse mode' output and any of the following:
 1. Output energy exceeding 1,5 J per pulse and "peak power" exceeding 50 W; or
 2. "Average output power" exceeding 80 W; or
 - b. 'Multiple transverse mode' output and any of the following:
 1. Output energy exceeding 1,5 J per pulse and "peak power" exceeding 150 W; or
 2. "Average output power" exceeding 150 W;

6A005.b. continued

4. Output wavelength exceeding 540 nm but not exceeding 800 nm and any of the following:
 - a. "Pulse duration" less than 1 ps and any of the following:
 1. Output energy exceeding 0,005 J per pulse and "peak power" exceeding 5 GW; or
 2. "Average output power" exceeding 20 W; or
 - b. "Pulse duration" equal to or exceeding 1 ps and any of the following:
 1. Output energy exceeding 1,5 J per pulse and "peak power" exceeding 30 W; or
 2. "Average output power" exceeding 30 W;
5. Output wavelength exceeding 800 nm but not exceeding 975 nm and any of the following:
 - a. "Pulse duration" less than 1 ps and any of the following:
 1. Output energy exceeding 0,005 J per pulse and "peak power" exceeding 5 GW; or
 2. 'Single transverse mode' output and "average output power" exceeding 20 W;
 - b. "Pulse duration" equal to or exceeding 1 ps and not exceeding 1 μ s and any of the following:
 1. Output energy exceeding 0,5 J per pulse and "peak power" exceeding 50 W;
 2. 'Single transverse mode' output and "average output power" exceeding 20 W; or
 3. 'Multiple transverse mode' output and "average output power" exceeding 50 W; or

6A005.b.5. continued

- c. "Pulse duration" exceeding 1 μ s and any of the following:
 - 1. Output energy exceeding 2 J per pulse and "peak power" exceeding 50 W;
 - 2. 'Single transverse mode' output and "average output power" exceeding 50 W; or
 - 3. 'Multiple transverse mode' output and "average output power" exceeding 80 W;
- 6. Output wavelength exceeding 975 nm but not exceeding 1 150 nm and any of the following:
 - a. "Pulse duration" of less than 1 ps, and any of the following:
 - 1. Output "peak power" exceeding 2 GW per pulse;
 - 2. "Average output power" exceeding 30 W; or
 - 3. Output energy exceeding 0,002 J per pulse;
 - b. "Pulse duration" equal to or exceeding 1 ps and less than 1 ns and any of the following:
 - 1. Output "peak power" exceeding 5 GW per pulse;
 - 2. "Average output power" exceeding 50 W; or
 - 3. Output energy exceeding 0,1 J per pulse;
 - c. "Pulse duration" equal to or exceeding 1 ns but not exceeding 1 μ s, and any of the following:
 - 1. 'Single transverse mode' output and any of the following:
 - a. "Peak power" exceeding 100 MW;
 - b. "Average output power" exceeding 20 W limited by design to a maximum pulse repetition frequency less than or equal to 1 kHz;

6A005.b.6.c.1. continued

- c. "Wall-plug efficiency" exceeding 12%, "average output power" exceeding 100 W and capable of operating at a pulse repetition frequency greater than 1 kHz;
 - d. "Average output power" exceeding 150 W and capable of operating at a pulse repetition frequency greater than 1 kHz; or
 - e. Output energy exceeding 2 J per pulse; or
2. 'Multiple transverse mode' output and any of the following:
- a. "Peak power" exceeding 400 MW;
 - b. "Wall-plug efficiency" exceeding 18% and "average output power" exceeding 500 W;
 - c. "Average output power" exceeding 2 kW; or
 - d. Output energy exceeding 4 J per pulse; or

- d. "Pulse duration" exceeding 1 μ s and any of the following:
 - 1. 'Single transverse mode' output and any of the following:
 - a. "Peak power" exceeding 500 kW;
 - b. "Wall-plug efficiency" exceeding 12% and "average output power" exceeding 100 W; or
 - c. "Average output power" exceeding 150 W; or
 - 2. 'Multiple transverse mode' output and any of the following:
 - a. "Peak power" exceeding 1 MW;
 - b. "Wall-plug efficiency" exceeding 18% and "average output power" exceeding 500 W; or
 - c. "Average output power" exceeding 2 kW;
- 7. Output wavelength exceeding 1 150 nm but not exceeding 1 555 nm, and any of the following:
 - a. "Pulse duration" not exceeding 1 μ s and any of the following:
 - 1. Output energy exceeding 0,5 J per pulse and "peak power" exceeding 50 W;
 - 2. 'Single transverse mode' output and "average output power" exceeding 20 W; or
 - 3. 'Multiple transverse mode' output and "average output power" exceeding 50 W; or
 - b. "Pulse duration" exceeding 1 μ s and any of the following:
 - 1. Output energy exceeding 2 J per pulse and "peak power" exceeding 50 W;
 - 2. 'Single transverse mode' output and "average output power" exceeding 50 W; or
 - 3. 'Multiple transverse mode' output and "average output power" exceeding 80 W;

6A005.b. continued

8. Output wavelength exceeding 1 555 nm but not exceeding 1 850 nm, and any of the following:
 - a. Output energy exceeding 100 mJ per pulse and "peak power" exceeding 1 W; or
 - b. "Average output power" exceeding 1 W;
9. Output wavelength exceeding 1 850 nm but not exceeding 2 100 nm, and any of the following
 - a. 'Single transverse mode' and any of the following:
 1. Output energy exceeding 100 mJ per pulse and "peak power" exceeding 1 W; or
 2. "Average output power" exceeding 1 W; or
 - b. 'Multiple transverse mode' and any of the following:
 1. Output energy exceeding 100 mJ per pulse and "peak power" exceeding 10 kW; or
 2. "Average output power" exceeding 120 W; or
10. Output wavelength exceeding 2 100 nm and any of the following:
 - a. Output energy exceeding 100 mJ per pulse and "peak power" exceeding 1 W; or
 - b. "Average output power" exceeding 1 W;

- c. "Tunable" "lasers" having any of the following:
 1. Output wavelength less than 600 nm and any of the following:
 - a. Output energy exceeding 50 mJ per pulse and "peak power" exceeding 1 W; or
 - b. Average or CW output power exceeding 1 W;

Note: 6A005.c.1. does not control dye "lasers" or other liquid "lasers", having a multimode output and a wavelength of 150 nm or more but not exceeding 600 nm and all of the following:

 1. *Output energy less than 1,5 J per pulse or a "peak power" less than 20 W; and*
 2. *Average or CW output power less than 20 W.*
 2. Output wavelength of 600 nm or more but not exceeding 1 400 nm, and any of the following:
 - a. Output energy exceeding 1 J per pulse and "peak power" exceeding 20 W; or
 - b. Average or CW output power exceeding 20 W; or
 3. Output wavelength exceeding 1 400 nm and any of the following:
 - a. Output energy exceeding 50 mJ per pulse and "peak power" exceeding 1 W; or
 - b. Average or CW output power exceeding 1 W;

Note: 6A005.c.3. does not control "tunable" "lasers" having an average or CW output power exceeding 1 W and not exceeding 10 W, power consumption equal to or exceeding 250 W, and a total mass greater than 50 kg. For the purposes of this Note, total mass includes all components required to operate the "laser", e.g., "laser", power supply, heat exchanger, but excludes external optics for beam conditioning or delivery.
- d. Other "lasers", not specified in 6A005.a., 6A005.b. or 6A005.c. as follows:
 1. Semiconductor "lasers" as follows:

Note 1: 6A005.d.1. includes semiconductor "lasers" having optical output connectors (e.g., fibre optic pigtails).

Note 2: The control status of semiconductor "lasers" specially designed for other equipment is determined by the control status of the other equipment.

Technical Notes:

For the purposes of 6A005.d.1.:

 1. *Semiconductor "lasers" are commonly called "laser" diodes.*
 2. *A 'bar' (also called a semiconductor "laser" 'bar', a "laser" diode 'bar' or diode 'bar') consists of multiple semiconductor "lasers" in a one-dimensional array.*
 3. *A 'stacked array' consists of multiple 'bars' forming a two-dimensional array of semiconductor "lasers".*

6A005.d.1. continued

- a. Individual single-transverse mode semiconductor "lasers" having any of the following:
 - 1. Wavelength equal to or less than 1 570 nm and average or CW output power exceeding 2,0 W; or
 - 2. Wavelength greater than 1 570 nm and average or CW output power exceeding 500 mW;
- b. Individual multiple-transverse mode semiconductor "lasers" having any of the following:
 - 1. Wavelength of less than 780 nm and average or CW output power exceeding 25 W;
 - 2. Wavelength equal to or greater than 780 nm and less than 1 100 nm and average or CW output power exceeding 30 W;
 - 3. Wavelength equal to or greater than 1 100 nm and less than 1 400 nm and average or CW output power exceeding 25 W;
 - 4. Wavelength equal to or greater than 1 400 nm and less than 1 900 nm and average or CW output power exceeding 2,5 W; or
 - 5. Wavelength equal to or greater than 1 900 nm and average or CW output power exceeding 1 W;
- c. Individual semiconductor "laser" 'bars', having any of the following:
 - 1. Wavelength of less than 1 400 nm and average or CW output power exceeding 100 W;
 - 2. Wavelength equal to or greater than 1 400 nm and less than 1 900 nm and average or CW output power exceeding 25 W; or
 - 3. Wavelength equal to or greater than 1 900 nm and average or CW output power exceeding 10 W;

- d. Semiconductor "laser" 'stacked arrays' (two-dimensional arrays) having any of the following:
 - 1. Wavelength less than 1 400 nm and having any of the following:
 - a. Average or CW total output power less than 3 kW and having average or CW output 'power density' greater than 500 W/cm²;
 - b. Average or CW total output power equal to or exceeding 3 kW but less than or equal to 5 kW, and having average or CW output 'power density' greater than 350 W/cm²;
 - c. Average or CW total output power exceeding 5 kW;
 - d. Peak pulsed 'power density' exceeding 2 500 W/cm²; or
Note: 6A005.d.1.d.1.d. does not control epitaxially-fabricated monolithic devices.
 - e. Spatially coherent average or CW total output power, greater than 150 W;
 - 2. Wavelength greater than or equal to 1 400 nm but less than 1 900 nm, and having any of the following:
 - a. Average or CW total output power less than 250 W and average or CW output 'power density' greater than 150 W/cm²;
 - b. Average or CW total output power equal to or exceeding 250 W but less than or equal to 500 W, and having average or CW output 'power density' greater than 50 W/cm²;
 - c. Average or CW total output power exceeding 500 W;
 - d. Peak pulsed 'power density' exceeding 500 W/cm²; or
Note: 6A005.d.1.d.2.d. does not control epitaxially-fabricated monolithic devices.
 - e. Spatially coherent average or CW total output power, exceeding 15 W;

3. Wavelength greater than or equal to 1 900 nm and having any of the following:
 - a. Average or CW output 'power density' greater than 50 W/cm²;
 - b. Average or CW output power greater than 10 W; or
 - c. Spatially coherent average or CW total output power, exceeding 1,5 W; or
4. At least one "laser" 'bar' specified in 6A005.d.1.c.;

Technical Note:

For the purposes of 6A005.d.1.d., 'power density' means the total "laser" output power divided by the emitter surface area of the 'stacked array'.

- e. Semiconductor "laser" 'stacked arrays', other than those specified in 6A005.d.1.d., having all of the following:
 1. Specially designed or modified to be combined with other 'stacked arrays' to form a larger 'stacked array'; and
 2. Integrated connections, common for both electronics and cooling;

Note 1: *'Stacked arrays', formed by combining semiconductor "laser" 'stacked arrays' specified in 6A005.d.1.e., that are not designed to be further combined or modified are specified in 6A005.d.1.d.*

Note 2: *'Stacked arrays', formed by combining semiconductor "laser" 'stacked arrays' specified in 6A005.d.1.e., that are designed to be further combined or modified are specified in 6A005.d.1.e.*

Note 3: *6A005.d.1.e. does not control modular assemblies of single 'bars' designed to be fabricated into end-to-end stacked linear arrays.*

6A005.d. continued

2. Carbon monoxide (CO) "lasers" having any of the following:
 - a. Output energy exceeding 2 J per pulse and "peak power" exceeding 5 kW; or
 - b. Average or CW output power exceeding 5 kW;
3. Carbon dioxide (CO₂) "lasers" having any of the following:
 - a. CW output power exceeding 15 kW;
 - b. Pulsed output with a "pulse duration" exceeding 10 µs and any of the following:
 1. "Average output power" exceeding 10 kW; or
 2. "Peak power" exceeding 100 kW; or
 - c. Pulsed output with a "pulse duration" equal to or less than 10 µs and any of the following:
 1. Pulse energy exceeding 5 J per pulse; or
 2. "Average output power" exceeding 2,5 kW;
4. Excimer "lasers" having any of the following:
 - a. Output wavelength not exceeding 150 nm and any of the following:
 1. Output energy exceeding 50 mJ per pulse; or
 2. "Average output power" exceeding 1 W;
 - b. Output wavelength exceeding 150 nm but not exceeding 190 nm and any of the following:
 1. Output energy exceeding 1,5 J per pulse; or
 2. "Average output power" exceeding 120 W;
 - c. Output wavelength exceeding 190 nm but not exceeding 360 nm and any of the following:
 1. Output energy exceeding 10 J per pulse; or
 2. "Average output power" exceeding 500 W; or

6A005.d.4. continued

- d. Output wavelength exceeding 360 nm and any of the following:
 - 1. Output energy exceeding 1,5 J per pulse; or
 - 2. "Average output power" exceeding 30 W;

N.B. For excimer "lasers" specially designed for lithography equipment, see 3B001.

- 5. 'Chemical lasers' as follows:

Technical Note:

For the purposes of 6A005.d.5., 'chemical laser' is a "laser" in which the excited species is produced by the output energy from a chemical reaction.

- a. Hydrogen Fluoride (HF) "lasers";
- b. Deuterium Fluoride (DF) "lasers";
- c. 'Transfer lasers' as follows:
 - 1. Oxygen Iodine (O₂-I) "lasers";
 - 2. Deuterium Fluoride-Carbon dioxide (DF-CO₂) "lasers";

Technical Note:

For the purposes of 6A005.d.5.c., 'transfer lasers' are "lasers" in which the lasing species are excited through the transfer of energy by collision of a non- lasing atom or molecule with a lasing atom or molecule species.

- 6. "Non-repetitive pulsed" Nd:glass "lasers" having any of the following:
 - a. "Pulse duration" not exceeding 1 µs and output energy exceeding 50 J per pulse; or
 - b. "Pulse duration" exceeding 1 µs and output energy exceeding 100 J per pulse;

6A005 continued

e. Components as follows:

1. Mirrors cooled either by 'active cooling' or by heat pipe cooling;

Technical Note:

For the purposes of 6A005.e.1., 'active cooling' is a cooling technique for optical components using flowing fluids within the subsurface (nominally less than 1 mm below the optical surface) of the optical component to remove heat from the optic.

2. Optical mirrors or transmissive or partially transmissive optical or electro-optical components, other than fused tapered fibre combiners and Multi-Layer Dielectric gratings (MLDs), specially designed for use with specified "lasers";

Note: *Fibre combiners and MLDs are specified in 6A005.e.3.*

3. Fibre "laser" components as follows:
 - a. Multimode to multimode fused tapered fibre combiners having all of the following:
 1. An insertion loss better (less) than or equal to 0,3 dB maintained at a rated total average or CW output power (excluding output power transmitted through the single mode core if present) exceeding 1 000 W; and
 2. Number of input fibres equal to or greater than 3;
 - b. Single mode to multimode fused tapered fibre combiners having all of the following:
 1. An insertion loss better (less) than 0,5 dB maintained at a rated total average or CW output power exceeding 4 600 W;
 2. Number of input fibres equal to or greater than 3; and
 3. Having any of the following:
 - a. A Beam Parameter Product (BPP) measured at the output not exceeding 1,5 mm mrad for a number of input fibres less than or equal to 5; or
 - b. A BPP measured at the output not exceeding 2,5 mm mrad for a number of input fibres greater than 5;
 - c. MLDs having all of the following:
 1. Designed for spectral or coherent beam combination of 5 or more fibre "lasers"; and
 2. CW "Laser" Induced Damage Threshold (LIDT) greater than or equal to 10 kW/cm²;

6A005 continued

f. Optical equipment as follows:

N.B. For shared aperture optical elements, capable of operating in "Super High Power Laser" ("SHPL") applications, see the Military Goods Controls.

1. Not used;
2. "Laser" diagnostic equipment specially designed for dynamic measurement of "SHPL" system angular beam steering errors and having an angular "accuracy" of 10 μ rad (microradians) or less (better);
3. Optical equipment and components, specially designed for coherent beam combination in a phased-array "SHPL" system and having any of the following:
 - a. An "accuracy" of 0,1 μ m or less (better), for wavelengths greater than 1 μ m; or
 - b. An "accuracy" of $\lambda/10$ or less (better) at the designed wavelength, for wavelengths equal to or less than 1 μ m;
4. Projection telescopes specially designed for use with "SHPL" systems;

g. 'Laser acoustic detection equipment' having all of the following:

1. CW "laser" output power equal to or exceeding 20 mW;
2. "Laser" frequency stability equal to or less (better) than 10 MHz;
3. "Laser" wavelengths equal to or exceeding 1 000 nm but not exceeding 2 000 nm;
4. Optical system resolution less (better) than 1 nm; and
5. Optical Signal to Noise ratio equal to or exceeding 10^3 .

Technical Note:

For the purposes of 6A005.g., 'laser acoustic detection equipment' is sometimes referred to as a "Laser" Microphone or Particle Flow Detection Microphone.

6A006 "Magnetometers", "magnetic gradiometers", "intrinsic magnetic gradiometers", underwater electric field sensors, "compensation systems", and specially designed components therefor, as follows:

N.B. SEE ALSO 7A103.d.

Note: 6A006 does not control instruments specially designed for fishery applications or biomagnetic measurements for medical diagnostics.

- a. "Magnetometers" and subsystems as follows:
 1. "Magnetometers" using "superconductive" (SQUID) "technology" and having any of the following:
 - a. SQUID systems designed for stationary operation, without specially designed subsystems designed to reduce in-motion noise, and having a 'sensitivity' equal to or less (better) than 50 fT (rms) per square root Hz at a frequency of 1 Hz; or
 - b. SQUID systems having an in-motion-magnetometer 'sensitivity' less (better) than 20 pT (rms) per square root Hz at a frequency of 1 Hz and specially designed to reduce in-motion noise;
 2. "Magnetometers" using optically pumped or nuclear precession (proton/Overhauser) "technology" having a 'sensitivity' less (better) than 20 pT (rms) per square root Hz at a frequency of 1 Hz;
 3. "Magnetometers" using fluxgate "technology" having a 'sensitivity' equal to or less (better) than 10 pT (rms) per square root Hz at a frequency of 1 Hz;
 4. Induction coil "magnetometers" having a 'sensitivity' less (better) than any of the following:
 - a. 0,05 nT (rms) per square root Hz at frequencies of less than 1 Hz;
 - b. 1×10^{-3} nT (rms) per square root Hz at frequencies of 1 Hz or more but not exceeding 10 Hz; or
 - c. 1×10^{-4} nT (rms) per square root Hz at frequencies exceeding 10 Hz;
 5. Fibre optic "magnetometers" having a 'sensitivity' less (better) than 1 nT (rms) per square root Hz;

6A006 continued

- b. Underwater electric field sensors having a 'sensitivity' less (better) than 8 nanovolt per metre per square root Hz when measured at 1 Hz;
- c. "Magnetic gradiometers" as follows:
 - 1. "Magnetic gradiometers" using multiple "magnetometers" specified in 6A006.a.;
 - 2. Fibre optic "intrinsic magnetic gradiometers" having a magnetic gradient field 'sensitivity' less (better) than 0,3 nT/m rms per square root Hz;
 - 3. "Intrinsic magnetic gradiometers", using "technology" other than fibre-optic "technology", having a magnetic gradient field 'sensitivity' less (better) than 0,015 nT/m rms per square root Hz;
- d. "Compensation systems" for magnetic or underwater electric field sensors resulting in a performance equal to or better than the parameters specified in 6A006.a., 6A006.b. or 6A006.c.;
- e. Underwater electromagnetic receivers incorporating magnetic field sensors specified in 6A006.a. or underwater electric field sensors specified in 6A006.b.

Technical Note:

For the purposes of 6A006, 'sensitivity' (noise level) is the root mean square of the device-limited noise floor which is the lowest signal that can be measured.

6A007 Gravity meters (gravimeters) and gravity gradiometers, as follows:

N.B. SEE ALSO 6A107.

- a. Gravity meters designed or modified for ground use and having a static "accuracy" of less (better) than 10 μ Gal;

Note: 6A007.a. does not control ground gravity meters of the quartz element (Worden) type.

- b. Gravity meters designed for mobile platforms and having all of the following:
 - 1. A static "accuracy" of less (better) than 0,7 mGal; and
 - 2. An in-service (operational) "accuracy" of less (better) than 0,7 mGal having a "time-to-steady-state registration" of less than 2 minutes under any combination of attendant corrective compensations and motional influences;
- c. Gravity gradiometers.

6A008 Radar systems, equipment and assemblies, having any of the following, and specially designed components therefor:

N.B. SEE ALSO 6A108.

Note: 6A008 does not control:

- Secondary surveillance radar (SSR);
- Civil Automotive Radar;
- Displays or monitors used for air traffic control (ATC);
- Meteorological (weather) radar;
- Precision approach radar (PAR) equipment conforming to International Civil Aviation Organization (ICAO) standards and employing electronically steerable linear (1-dimensional) arrays or mechanically positioned passive antennae.

a. Operating at frequencies from 40 GHz to 230 GHz and having any of the following:

1. An average output power exceeding 100 mW; or
2. Locating "accuracy" of 1 m or less (better) in range and 0,2 degree or less (better) in azimuth;

b. A "tunable" bandwidth exceeding $\pm 6,25\%$ of the 'centre operating frequency';

Technical Note:

For the purposes of 6A008.b., the 'centre operating frequency' equals one half of the sum of the highest plus the lowest specified operating frequencies.

c. Capable of operating simultaneously on more than two carrier frequencies;

d. Capable of operating in Synthetic Aperture Radar (SAR) mode, Inverse Synthetic Aperture Radar (ISAR) mode, or Sidelooking Airborne Radar (SLAR) mode;

e. Incorporating electronically scanned array antennae;

Technical Note:

For the purposes of 6A008.e., electronically scanned array antennae are also known as electronically steerable array antennae.

f. Capable of heightfinding non-cooperative targets;

6A008 continued

- g. Specially designed for airborne (balloon or airframe mounted) operation and having Doppler "signal processing" for the detection of moving targets;
- h. Employing processing of radar signals and using any of the following:
 - 1. "Radar spread spectrum" techniques; or
 - 2. 'Radar frequency agility' techniques;

Technical Note:

For the purposes of 6A008.h., 'radar frequency agility' applies to any technique which changes, in a pseudo-random sequence, the carrier frequency of a pulsed radar transmitter between pulses or between groups of pulses by an amount equal to or larger than the pulse bandwidth.

- i. Providing ground-based operation with a maximum 'instrumented range' exceeding 185 km;

Note: 6A008.i. does not control:

- a. Fishing ground surveillance radar;
- b. Ground radar equipment specially designed for enroute air traffic control and having all the following:
 - 1. A maximum 'instrumented range' of 500 km or less;
 - 2. Configured so that radar target data can be transmitted only one way from the radar site to one or more civil ATC centres;
 - 3. Contains no provisions for remote control of the radar scan rate from the enroute ATC centre; and
 - 4. Permanently installed;
- c. Weather balloon tracking radars.

Technical Note:

For the purposes of 6A008.i. 'instrumented range' is the specified unambiguous display range of a radar.

- j. Being "laser" radar or Light Detection and Ranging (LIDAR) equipment and having any of the following:
 - 1. "Space-qualified";
 - 2. Employing coherent heterodyne or homodyne detection techniques and having an angular resolution of less (better) than 20 μ rad (microradians);
or
 - 3. Designed for carrying out airborne bathymetric littoral surveys to International Hydrographic Organization (IHO) Order 1a Standard (5th Edition February 2008) for Hydrographic Surveys or better, and using one or more "lasers" with a wavelength exceeding 400 nm but not exceeding 600 nm;

Note 1: *LIDAR equipment specially designed for surveying is only specified in 6A008.j.3.*

Note 2: *6A008.j. does not control LIDAR equipment specially designed for meteorological observation.*

Note 3: *Parameters in the IHO Order 1a Standard (5th Edition February 2008) are summarised as follows:*

- *Horizontal Accuracy (95% Confidence Level) = 5 m + 5% of depth.*
- *Depth Accuracy for Reduced Depths (95% confidence level) = $\pm\sqrt{(a^2 + (b \times d)^2)}$, where:
*a = 0,5 m = constant depth error,
i.e., the sum of all constant depth errors
b = 0,013 = factor of depth dependent error
b x d = depth dependent error,
i.e., the sum of all depth dependent errors
d = depth**
- *Feature Detection = Cubic features > 2 m in depths up to 40 m; 10% of depth beyond 40 m.*

k. Having "signal processing" sub-systems using "pulse compression" and having any of the following:

1. A "pulse compression" ratio exceeding 150; or
2. A compressed pulse width of less than 200 ns; or

Note: *6A008.k.2. does not control two dimensional 'marine radar' or 'vessel traffic service' radar, having all of the following;*

- a. *"Pulse compression" ratio not exceeding 150;*
- b. *Compressed pulse width of greater than 30 ns;*
- c. *Single and rotating mechanically scanned antenna;*
- d. *Peak output power not exceeding 250 W; and*
- e. *Not capable of "frequency hopping".*

6A008 continued

1. Having data processing sub-systems and having any of the following:
 1. 'Automatic target tracking' providing, at any antenna rotation, the predicted target position beyond the time of the next antenna beam passage; or

Note: 6A008.l.1. does not control conflict alert capability in ATC systems, or 'marine radar'.

Technical Note:

For the purposes of 6A008.l.1., 'automatic target tracking' is a processing technique that automatically determines and provides as output an extrapolated value of the most probable position of the target in real time.

2. Not used;
3. Not used;
4. Configured to provide superposition and correlation, or fusion, of target data within six seconds from two or more 'geographically dispersed' radar sensors to improve the aggregate performance beyond that of any single sensor specified in 6A008.f. or 6A008.i.

Technical Note:

For the purposes of 6A008.l.4., sensors are considered 'geographically dispersed' when each location is distant from any other more than 1 500 m in any direction. Mobile sensors are always considered 'geographically dispersed'.

N.B. See also Military Goods Controls.

Note: 6A008.l.4. does not control systems, equipment and assemblies designed for 'vessel traffic service'.

Technical Notes:

For the purposes of 6A008:

1. 'Marine radar' is a radar that is designed to navigate safely at sea, inland waterways or near-shore environments.
2. 'Vessel traffic service' is a vessel traffic monitoring and control service similar to air traffic control for "aircraft".

6A102 Radiation hardened 'detectors', other than those specified in 6A002, specially designed or modified for protecting against nuclear effects (e.g. electromagnetic pulse (EMP), X-rays, combined blast and thermal effects) and usable for "missiles", designed or rated to withstand radiation levels which meet or exceed a total irradiation dose of 5×10^5 rads (silicon).

Technical Note:

In 6A102, a 'detector' is defined as a mechanical, electrical, optical or chemical device that automatically identifies and records, or registers a stimulus such as an environmental change in pressure or temperature, an electrical or electromagnetic signal or radiation from a radioactive material. This includes devices that sense by one time operation or failure.

6A107 Gravity meters (gravimeters) and components for gravity meters and gravity gradiometers, as follows:

- a. Gravity meters, other than those specified in 6A007.b., designed or modified for airborne or marine use, and having a static or operational accuracy equal to or less (better) than 0,7 milligal (mGal), and having a time-to-steady-state registration of two minutes or less;
- b. Specially designed components for gravity meters specified in 6A007.b. or 6A107.a. and gravity gradiometers specified in 6A007.c.

6A108 Radar systems, tracking systems and radomes, other than those specified in entry 6A008, as follows:

- a. Radar and laser radar systems designed or modified for use in space launch vehicles specified in 9A004 or sounding rockets specified in 9A104;

Note: 6A108.a. includes the following:

- a. *Terrain contour mapping equipment;*
- b. *Scene mapping and correlation (both digital and analogue) equipment;*
- c. *Doppler navigation radar equipment;*
- d. *Passive interferometer equipment;*
- e. *Imaging sensor equipment (both active and passive).*

- b. Precision tracking systems, usable for 'missiles', as follows:

1. Tracking systems which use a code translator in conjunction with either surface or airborne references or navigation satellite systems to provide real-time measurements of in-flight position and velocity;
2. Range instrumentation radars including associated optical/infrared trackers with all of the following capabilities:
 - a. Angular resolution better than 1,5 milliradians;
 - b. Range of 30 km or greater with a range resolution better than 10 m rms; and
 - c. Velocity resolution better than 3 m/s;

Technical Note:

In 6A108.b. 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.

- c. Radomes designed to withstand a combined thermal shock greater than $4,184 \times 10^6$ J/m² accompanied by a peak over pressure of greater than 50 kPa, and usable in "missiles" for protecting against nuclear effects (e.g. electromagnetic pulse (EMP), X-rays, combined blast and thermal effects).

6A202 Photomultiplier tubes having both of the following characteristics:

- a. Photocathode area of greater than 20 cm²; and
- b. Anode pulse rise time of less than 1 ns.

6A203 Cameras and components, other than those specified in 6A003, as follows:

N.B.1. *"Software" specially designed to enhance or release the performance of a camera or imaging device to meet the characteristics of 6A203.a., 6A203.b. or 6A203.c. is specified in 6D203.*

N.B.2. *"Technology" in the form of codes or keys to enhance or release the performance of a camera or imaging device to meet the characteristics of 6A203.a., 6A203.b. or 6A203.c. is specified in 6E203.*

Note: *6A203.a. to 6A203.c. does not control cameras or imaging devices if they have hardware, "software" or "technology" constraints that limit the performance to less than that specified below, 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 6D203 to enhance or release the performance to meet the characteristics of 6A203; or*
3. *They require "technology" in the form of keys or codes as specified in 6E203 to enhance or release the performance to meet the characteristics of 6A203.*

a. Streak cameras, and specially designed components therefor, as follows:

1. Streak cameras with writing speeds greater than 0,5 mm/μs;
2. Electronic streak cameras capable of 50 ns or less time resolution;
3. Streak tubes for cameras specified in 6A203.a.2.;
4. Plug-ins specially designed for use with streak cameras which have modular structures and that enable the performance specifications in 6A203.a.1. or 6A203.a.2.;
5. Synchronizing electronics units, rotor assemblies consisting of turbines, mirrors and bearings specially designed for cameras specified in 6A203.a.1.;

6A203 continued

- b. Framing cameras, and specially designed components therefor, as follows:
 - 1. Framing cameras with recording rates greater than 225 000 frames per second;
 - 2. Framing cameras capable of 50 ns or less frame exposure time;
 - 3. Framing tubes and solid-state imaging devices having a fast image gating (shutter) time of 50 ns or less specially designed for cameras specified in 6A203.b.1. or 6A203.b.2.;
 - 4. Plug-ins specially designed for use with framing cameras which have modular structures and that enable the performance specifications in 6A203.b.1. or 6A203.b.2.;
 - 5. Synchronizing electronics units, rotor assemblies consisting of turbines, mirrors and bearings specially designed for cameras specified in 6A203.b.1. or 6A203.b.2.;

Technical Note:

In 6A203.b., high speed single frame cameras can be used alone to produce a single image of a dynamic event, or several such cameras can be combined in a sequentially-triggered system to produce multiple images of an event.

- c. Solid-state or electron tube cameras, and specially designed components therefor, as follows:
 - 1. Solid-state cameras or electron tube cameras with a fast image gating (shutter) time of 50 ns or less;
 - 2. Solid-state imaging devices and image intensifiers tubes having a fast image gating (shutter) time of 50 ns or less specially designed for cameras specified in 6A203.c.1.;
 - 3. Electro-optical shuttering devices (Kerr or Pockels cells) with a fast image gating (shutter) time of 50 ns or less;
 - 4. Plug-ins specially designed for use with cameras which have modular structures and that enable the performance specifications in 6A203.c.1.
- d. Radiation-hardened TV cameras, or lenses therefor, specially designed or rated as radiation hardened to withstand a total radiation dose greater than 50×10^3 Gy(silicon) (5×10^6 rad (silicon)) without operational degradation.

Technical Note:

The term Gy(silicon) refers to the energy in Joules per kilogram absorbed by an unshielded silicon sample when exposed to ionising radiation.

6A205 "Lasers", "laser" amplifiers and oscillators, other than those specified in 0B001.g.5., 0B001.h.6. and 6A005, as follows:

N.B. For copper vapour lasers, see 6A005.b.

- a. Argon ion "lasers" having both of the following characteristics:
 - 1. Operating at wavelengths between 400 nm and 515 nm; and
 - 2. An "average output power" greater than 40 W;
- b. Tunable pulsed single-mode dye laser oscillators having all of the following characteristics:
 - 1. Operating at wavelengths between 300 nm and 800 nm;
 - 2. An "average output power" greater than 1 W;
 - 3. A repetition rate greater than 1 kHz; and
 - 4. Pulse width less than 100 ns;
- c. Tunable pulsed dye laser amplifiers and oscillators, having all of the following characteristics:
 - 1. Operating at wavelengths between 300 nm and 800 nm;
 - 2. An "average output power" greater than 30 W;
 - 3. A repetition rate greater than 1 kHz; and
 - 4. Pulse width less than 100 ns;

Note: 6A205.c. does not control single mode oscillators.

6A205 continued

- d. Pulsed carbon dioxide (CO₂) "lasers" having all of the following characteristics:
 - 1. Operating at wavelengths between 9 000 nm and 11 000 nm;
 - 2. A repetition rate greater than 250 Hz;
 - 3. An "average output power" greater than 500 W; and
 - 4. Pulse width of less than 200 ns;
- e. Para-hydrogen Raman shifters designed to operate at 16 µm output wavelength and at a repetition rate greater than 250 Hz;
- f. Neodymium-doped (other than glass) "lasers" with an output wavelength between 1 000 and 1 100 nm having either of the following:
 - 1. Pulse-excited and Q-switched with a pulse duration equal to or more than 1 ns, and having either of the following:
 - a. A single-transverse mode output with an "average output power" greater than 40W; or
 - b. A multiple-transverse mode output having an average power greater than 50 W; or
 - 2. Incorporating frequency doubling to give an output wavelength between 500 and 550 nm with an "average output power" of more than 40 W;
- g. Pulsed carbon monoxide (CO) "lasers", other than those specified in 6A005.d.2., having all of the following:
 - 1. Operating at wavelengths between 5 000 and 6 000 nm;
 - 2. A repetition rate greater than 250 Hz;
 - 3. An "average output power" greater than 200 W; and
 - 4. Pulse width of less than 200 ns.

6A225 Velocity interferometers for measuring velocities exceeding 1 km/s during time intervals of less than 10 microseconds.

Note: 6A225 includes velocity interferometers such as VISARs (Velocity Interferometer Systems for Any Reflector), DLIs (Doppler Laser Interferometers), PDV (Photonic Doppler Velocimeters) also known as Het-V (Heterodyne Velocimeters) and microwave velocity interferometers including optic-microwave mixing velocimeters.

6A226 Pressure sensors, as follows:

- a. Shock pressure gauges capable of measuring pressures greater than 10 GPa, including gauges made with manganin, ytterbium, and polyvinylidene fluoride (PVDF) / polyvinyl difluoride (PVF₂);
- b. Quartz pressure transducers for pressures greater than 10 GPa.

6B Test, Inspection and Production Equipment

6B002 Masks and reticles, specially designed for optical sensors specified in 6A002.a.1.b. or 6A002.a.1.d.

6B004 Optical equipment as follows:

- a. Equipment for measuring absolute reflectance to an "accuracy" of equal to or less (better) than 0,1% of the reflectance value;
- b. Equipment other than optical surface scattering measurement equipment, having an unobscured aperture of more than 10 cm, specially designed for the non-contact optical measurement of a non-planar optical surface figure (profile) to an "accuracy" of 2 nm or less (better) against the required profile.

Note: 6B004 does not control microscopes.

6B007 Equipment to produce, align and calibrate land-based gravity meters with a static "accuracy" of less (better) than 0,1 mGal.

6B008 Pulse radar cross-section measurement systems having transmit pulse widths of 100 ns or less, and specially designed components therefor.

N.B. SEE ALSO 6B108.

6B108 Systems, other than those specified in 6B008, specially designed for radar cross section measurement usable for 'missiles' and their subsystems.

Technical Note:

In 6B108 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.

6C Materials

6C002 Optical sensor materials as follows:

- a. Elemental tellurium (Te) having a purity equal to or greater (better) than 99,9995%;
- b. Single crystals (including epitaxial wafers) of any of the following:
 1. Cadmium zinc telluride (CdZnTe), with zinc content of less than 6% by 'mole fraction';
 2. Cadmium telluride (CdTe) of any purity level; or
 3. Mercury cadmium telluride (HgCdTe) of any purity level.

Technical Note:

For the purposes of 6C002.b.1., 'mole fraction' is defined as the ratio of moles of ZnTe to the sum of moles of CdTe and ZnTe present in the crystal.

6C004 Optical materials as follows:

- a. Zinc selenide (ZnSe) and zinc sulphide (ZnS) "substrate blanks", produced by the Chemical Vapour Deposition (CVD) process and having any of the following:
 1. A volume greater than 100 cm³; or
 2. A diameter greater than 80 mm and a thickness of 20 mm or more;
- b. Electro-optic materials and non-linear optical materials, as follows:
 1. Potassium titanyl arsenate (KTA) (CAS 59400-80-5);
 2. Silver gallium selenide (AgGaSe₂, also known as AGSE) (CAS 12002-67-4);
 3. Thallium arsenic selenide (Tl₃AsSe₃, also known as TAS) (CAS 16142-89-5);
 4. Zinc germanium phosphide (ZnGeP₂, also known as ZGP, zinc germanium biphosphide or zinc germanium diphosphide);
 5. Gallium selenide (GaSe) (CAS 12024-11-2);

6C004 continued

- c. Non-linear optical materials, other than those specified in 6C004.b., having any of the following:
 - 1. Having all of the following:
 - a. Dynamic (also known as non-stationary) third order non-linear susceptibility ($\chi^{(3)}$, chi 3) of $10^{-6} \text{ m}^2/\text{V}^2$ or more; and
 - b. Response time of less than 1 ms; or
 - 2. Second order non-linear susceptibility ($\chi^{(2)}$, chi 2) of $3,3 \times 10^{-11} \text{ m/V}$ or more;
- d. "Substrate blanks" of silicon carbide or beryllium beryllium (Be/Be) deposited materials, exceeding 300 mm in diameter or major axis length;
- e. Glass, including fused silica, phosphate glass, fluorophosphate glass, zirconium fluoride (ZrF_4) (CAS 7783-64-4) and hafnium fluoride (HfF_4) (CAS 13709-52-9) and having all of the following:
 - 1. A hydroxyl ion (OH^-) concentration of less than 5 ppm;
 - 2. Integrated metallic purity levels of less than 1 ppm; and
 - 3. High homogeneity (index of refraction variance) less than 5×10^{-6} ;
- f. Synthetically produced diamond material with an absorption of less than 10^{-5} cm^{-1} for wavelengths exceeding 200 nm but not exceeding 14 000 nm.

6C005 "Laser" materials as follows:

- a. Synthetic crystalline "laser" host material in unfinished form as follows:
 - 1. Titanium doped sapphire;
 - 2. Not used.

6C005 continued

- b. Rare-earth-metal doped double-clad fibres having any of the following:
 - 1. Nominal "laser" wavelength of 975 nm to 1 150 nm and having all of the following:
 - a. Average core diameter equal to or greater than 25 μm ; and
 - b. Core 'Numerical Aperture' ('NA') less than 0,065; or
 - Note: 6C005.b.1. does not control double-clad fibres having an inner glass cladding diameter exceeding 150 μm and not exceeding 300 μm .*
 - 2. Nominal "laser" wavelength exceeding 1 530 nm and having all of the following:
 - a. Average core diameter equal to or greater than 20 μm ; and
 - b. Core 'Numerical Aperture' ('NA') less than 0,1.

Note: 6C005.b. includes fibres assembled with end caps.

Technical Note:

For the purposes of 6C005.b., the core 'Numerical Aperture' ('NA') is measured at the emission wavelengths of the fibre.

6D Software

- 6D001 "Software" specially designed for the "development" or "production" of equipment specified in 6A004, 6A005, 6A008 or 6B008.
- 6D002 "Software" specially designed for the "use" of equipment specified in 6A002.b., 6A008 or 6B008.

6D003 Other "software" as follows:

a. "Software" as follows:

1. "Software" specially designed for acoustic beam forming for the "real-time processing" of acoustic data for passive reception using towed hydrophone arrays;
2. "Source code" for the "real-time processing" of acoustic data for passive reception using towed hydrophone arrays;
3. "Software" specially designed for acoustic beam forming for "real-time processing" of acoustic data for passive reception using bottom or bay cable systems;
4. "Source code" for "real-time processing" of acoustic data for passive reception using bottom or bay cable systems;

6D003.a. continued

5. "Software" or "source code", specially designed for all of the following:
 - a. "Real-time processing" of acoustic data from sonar systems specified in 6A001.a.1.e.; and
 - b. Automatically detecting, classifying and determining the location of divers or swimmers;

N.B. For diver detection "software" or "source code", specially designed or modified for military use, SEE THE MILITARY GOODS CONTROLS.
- b. Not used;
- c. "Software" designed or modified for cameras incorporating "focal plane arrays" specified in 6A002.a.3.f. and designed or modified to remove a frame rate restriction and allow the camera to exceed the frame rate specified in 6A003.b.4. Note 3.a;
- d. "Software" specially designed to maintain the alignment and phasing of segmented mirror systems consisting of mirror segments having a diameter or major axis length equal to or larger than 1 m;
- e. Not used;
- f. "Software" as follows:
 1. "Software" specially designed for magnetic and electric field "compensation systems" for magnetic sensors designed to operate on mobile platforms;
 2. "Software" specially designed for magnetic and electric field anomaly detection on mobile platforms;
 3. "Software" specially designed for "real-time processing" of electromagnetic data using underwater electromagnetic receivers specified in 6A006.e.;
 4. "Source code" for "real time processing" of electromagnetic data using underwater electromagnetic receivers specified in 6A006.e.;
- g. "Software" specially designed to correct motional influences of gravity meters or gravity gradiometers;

6D003 continued

- h. "Software" as follows:
 - 1. Air Traffic Control (ATC) "software" designed to be hosted on general purpose computers located at Air Traffic Control centres and capable of accepting radar target data from more than four primary radars;
 - 2. "Software" for the design or "production" of radomes having all of the following:
 - a. Specially designed to protect the electronically scanned array antennae specified in 6A008.e.; and
 - b. Resulting in an antenna pattern having an 'average side lobe level' more than 40 dB below the peak of the main beam level.

Technical Note:

For the purposes of 6D003.h.2.b., 'average side lobe level' is measured over the entire array excluding the angular extent of the main beam and the first two side lobes on either side of the main beam.

- 6D102 "Software" specially designed or modified for the "use" of goods specified in 6A108.
- 6D103 "Software" which processes post-flight, recorded data, enabling determination of vehicle position throughout its flight path, specially designed or modified for 'missiles'.

Technical Note:

In 6D103 'missiles' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.

- 6D203 "Software" specially designed to enhance or release the performance of cameras or imaging devices to meet the characteristics of 6A203.a. to 6A203.c.

6E Technology

- 6E001 "Technology" according to the General Technology Note for the "development" of equipment, materials or "software" specified in 6A, 6B, 6C or 6D.
- 6E002 "Technology" according to the General Technology Note for the "production" of equipment or materials specified in 6A, 6B or 6C.
- 6E003 Other "technology" as follows:

a. "Technology" as follows:

1. "Technology" "required" for the coating and treatment of optical surfaces to achieve an 'optical thickness' uniformity of 99,5% or better for optical coatings 500 mm or more in diameter or major axis length and with a total loss (absorption and scatter) of less than 5×10^{-3} ;

N.B. See also 2E003.f.

Technical Note:

For the purposes of 6E003.a.1., 'optical thickness' is the mathematical product of the index of refraction and the physical thickness of the coating.

6E003.a. continued

2. "Technology" for the fabrication of optics using single point diamond turning techniques to produce surface finish "accuracies" of less (better) than 10 nm rms on non-planar surfaces exceeding 0,5 m²;
 - b. "Technology" "required" for the "development", "production" or "use" of specially designed diagnostic instruments or targets in test facilities for "SHPL" testing or testing or evaluation of materials irradiated by "SHPL" beams;
- 6E101 "Technology" according to the General Technology Note for the "use" of equipment or "software" specified in 6A002, 6A007.b. and .c., 6A008, 6A102, 6A107, 6A108, 6B108, 6D102 or 6D103.
- Note: 6E101 only controls "technology" for items specified in 6A002, 6A007 and 6A008 if the items were designed for airborne applications and are usable in "missiles".*
- 6E201 "Technology" according to the General Technology Note for the "use" of equipment specified in 6A003, 6A005.a.2., 6A005.b.2., 6A005.b.3., 6A005.b.4., 6A005.b.6., 6A005.c.2., 6A005.d.3.c., 6A005.d.4.c., 6A202, 6A203, 6A205, 6A225 or 6A226.
- Note 1: 6E201 only controls "technology" for cameras specified in 6A003 if the cameras are also specified by any of the control parameters of 6A203.*
- Note 2: 6E201 only controls "technology" for lasers in 6A005.b.6. that are neodymium-doped and specified by any of the control parameters of 6A205.f.*
- 6E203 "Technology", in the form of codes or keys, to enhance or release the performance of cameras or imaging devices to meet the characteristics of 6A203.a. to 6A203.c.

PART IX – Category 7

CATEGORY 7 - NAVIGATION AND AVIONICS

7A Systems, Equipment and Components

N.B. For automatic pilots for submersible vehicles, see Category 8.
For radar, see Category 6.

7A001 Accelerometers as follows and specially designed components therefor:

N.B. SEE ALSO 7A101.

N.B. For angular or rotational accelerometers, see 7A001.b.

- a. Linear accelerometers having any of the following:
 1. Specified to function at linear acceleration levels less than or equal to 15 g and having any of the following:
 - a. A "bias" "stability" of less (better) than 130 micro g with respect to a fixed calibration value over a period of one year; or
 - b. A "scale factor" "stability" of less (better) than 130 ppm with respect to a fixed calibration value over a period of one year;
 2. Specified to function at linear acceleration levels exceeding 15 g but less than or equal to 100 g and having all of the following:
 - a. A "bias" "repeatability" of less (better) than 1 250 micro g over a period of one year; and
 - b. A "scale factor" "repeatability" of less (better) than 1 250 ppm over a period of one year; or
 3. Designed for use in inertial navigation or guidance systems and specified to function at linear acceleration levels exceeding 100 g;
- Note: 7A001.a.1. and 7A001.a.2. do not control accelerometers limited to measurement of only vibration or shock.
- b. Angular or rotational accelerometers, specified to function at linear acceleration levels exceeding 100 g.

7A002 Gyros or angular rate sensors, having any of the following and specially designed components therefor:

N.B. SEE ALSO 7A102.

N.B. For angular or rotational accelerometers, see 7A001.b.

a. Specified to function at linear acceleration levels less than or equal to 100 g and having any of the following:

1. An angular rate range of less than 500 degrees per second and having any of the following:

a. A "bias" "stability" of less (better) than 0,5 degree per hour, when measured in a 1 g environment over a period of one month, and with respect to a fixed calibration value; or

b. An "angle random walk" of less (better) than or equal to 0,0035 degree per square root hour; or

Note: 7A002.a.1.b. does not control "spinning mass gyros".

2. An angular rate range greater than or equal to 500 degrees per second and having any of the following:

a. A "bias" "stability" of less (better) than 4 degrees per hour, when measured in a 1 g environment over a period of three minutes, and with respect to a fixed calibration value; or

b. An "angle random walk" of less (better) than or equal to 0,1 degree per square root hour; or

Note: 7A002.a.2.b. does not control "spinning mass gyros".

b. Specified to function at linear acceleration levels exceeding 100 g.

7A003 'Inertial measurement equipment or systems', having any of the following:

N.B. SEE ALSO 7A103.

Note: 7A003. does not apply to 'inertial measurement equipment or systems' which are certified for use on "civil aircraft" by civil aviation authorities of one or more Member States or Wassenaar Arrangement Participating States.

Technical Notes:

For the purposes of 7A003:

1. 'Inertial measurement equipment or systems' incorporate accelerometers or gyroscopes to measure changes in velocity and orientation in order to determine or maintain heading or position without requiring an external reference once aligned. 'Inertial measurement equipment or systems' include:
 - Attitude and Heading Reference Systems (AHRSSs);
 - Gyrocompasses;
 - Inertial Measurement Units (IMUs);
 - Inertial Navigation Systems (INSs);
 - Inertial Reference Systems (IRSs);
 - Inertial Reference Units (IRUs).
2. 'Positional aiding references' independently provide position, and include:
 - a. "Satellite navigation system";
 - b. "Data-Based Referenced Navigation" ("DBRN").

7A003 continued

- a. Designed for "aircraft", land vehicles or vessels, providing position without the use of 'positional aiding references', and having any of the following "accuracies" subsequent to normal alignment:
 - 1. 0,8 nautical miles per hour (nm/hr) "Circular Error Probable" ("CEP") rate or less (better);
 - 2. 0,5 % distanced travelled "CEP" or less (better); or
 - 3. Total drift of 1 nautical mile "CEP" or less (better) in a 24 hr period;

Technical Note:

For the purposes of 7A003.a.1., 7A003.a.2. and 7A003.a.3., the performance parameters typically apply to 'inertial measurement equipment or systems' designed for "aircraft", vehicles and vessels, respectively. These parameters result from the utilisation of specialised non-'positional aiding references' (e.g., altimeter, odometer, velocity log). As a consequence, the specified performance values cannot be readily converted between these parameters. Equipment designed for multiple platforms are evaluated against each applicable entry 7A003.a.1., 7A003.a.2., or 7A003.a.3.

7A003 continued

- b. Designed for "aircraft", land vehicles or vessels, with an embedded 'positional aiding reference' and providing position after loss of all 'positional aiding references' for a period of up to 4 minutes, having an "accuracy" of less (better) than 10 meters "CEP";

Note: 7A003.b. refers to systems in which 'inertial measurement equipment or systems' and other independent 'positional aiding references' are built into a single unit (i.e., embedded) in order to achieve improved performance.

- c. Designed for "aircraft", land vehicles or vessels, providing heading or True North determination and having any of the following:
 - 1. A maximum operating angular rate less (lower) than 500 deg/s and a heading "accuracy" without the use of 'positional aiding references' equal to or less (better) than 0,07 deg sec(Lat) (equivalent to 6 arc minutes rms at 45 degrees latitude); or
 - 2. A maximum operating angular rate equal to or greater (higher) than 500 deg/s and a heading "accuracy" without the use of 'positional aiding references' equal to or less (better) than 0,2 deg sec(Lat) (equivalent to 17 arc minutes rms at 45 degrees latitude); or
- d. Providing acceleration measurements or angular rate measurements, in more than one dimension, and having any of the following:
 - 1. Performance specified in 7A001 or 7A002 along any axis, without the use of any aiding references; or
 - 2. Being "space-qualified" and providing angular rate measurements having an "angle random walk" along any axis of less (better) than or equal to 0,1 degree per square root hour.

Note: 7A003.d.2. does not control 'inertial measurement equipment or systems' that contain "spinning mass gyros" as the only type of gyro.

7A004 'Star trackers' and components therefor, as follows:

N.B. SEE ALSO 7A104.

- a. 'Star trackers' with a specified azimuth "accuracy" of equal to or less (better) than 20 seconds of arc throughout the specified lifetime of the equipment;
- b. Components specially designed for equipment specified in 7A004.a. as follows:
 1. Optical heads or baffles;
 2. Data processing units.

Technical Note:

For the purposes of 7A004.a., 'star trackers' are also referred to as stellar attitude sensors or gyro-astro compasses.

7A005 "Satellite navigation system" receiving equipment having any of the following and specially designed components therefor:

N.B. SEE ALSO 7A105.

N.B. For equipment specially designed for military use, SEE MILITARY GOODS CONTROLS.

- a. Employing a decryption algorithm specially designed or modified for government use to access the ranging code for position and time; or
- b. Employing 'adaptive antenna systems'.

Note: 7A005.b. does not control "satellite navigation system" receiving equipment that only uses components designed to filter, switch, or combine signals from multiple omni-directional antennae that do not implement adaptive antenna techniques.

Technical Note:

For the purposes of 7A005.b., 'adaptive antenna systems' dynamically generate one or more spatial nulls in an antenna array pattern by signal processing in the time domain or frequency domain.

7A006 Airborne altimeters operating at frequencies other than 4,2 to 4,4 GHz inclusive and having any of the following:

N.B. SEE ALSO 7A106.

- a. 'Power management'; or
- b. Using phase shift key modulation.

Technical Note:

For the purposes of 7A006.a., 'power management' is changing the transmitted power of the altimeter signal so that received power at the "aircraft" altitude is always at the minimum necessary to determine the altitude.

7A008 Underwater sonar navigation systems using doppler velocity or correlation velocity logs integrated with a heading source and having a positioning "accuracy" of equal to or less (better) than 3% of distance travelled "Circular Error Probable" ("CEP") and specially designed components therefor.

Note: 7A008 does not control systems specially designed for installation on surface vessels or systems requiring acoustic beacons or buoys to provide positioning data.

N.B. For acoustic systems, see 6A001.a., and for correlation-velocity and Doppler-velocity sonar log equipment, see 6A001.b.
For other marine systems, see 8A002.

7A101 Linear accelerometers, other than those specified in 7A001, designed for use in inertial navigation systems or in guidance systems of all types, usable in 'missiles', having all of the following characteristics, and specially designed components therefor:

- a. A "bias" "repeatability" of less (better) than 1 250 micro g; and
- b. A "scale factor" "repeatability" of less (better) than 1 250 ppm;

Note: 7A101 does not control accelerometers specially designed and developed as Measurement While Drilling (MWD) Sensors for use in downhole well service operations.

Technical Notes:

1. In 7A101 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km;
2. In 7A101 the measurement of "bias" and "scale factor" refers to one sigma standard deviation with respect to a fixed calibration over a period of one year;

- 7A102 All types of gyros, other than those specified in 7A002, usable in 'missiles', with a rated "drift rate" 'stability' of less than 0,5° (1 sigma or rms) per hour in a 1 g environment and specially designed components therefor.

Technical Notes:

1. In 7A102 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.
2. In 7A102 'stability' is defined as a measure of the ability of a specific mechanism or performance coefficient to remain invariant when continuously exposed to a fixed operating condition (IEEE STD 528-2001 point 2.247).

- 7A103 Instrumentation, navigation equipment and systems, other than those specified in 7A003, as follows; and specially designed components therefor:

- a. 'Inertial measurement equipment or systems', using accelerometers or gyros as follows:

1. Accelerometers specified in 7A001.a.3., 7A001.b. or 7A101 or gyros specified in 7A002 or 7A102; or

Note: 7A103.a.1. does not control equipment containing accelerometers specified in 7A001.a.3. that are designed to measure vibration or shock.

2. Accelerometers specified in 7A001.a.1. or 7A001.a.2., designed for use in inertial navigation systems or in guidance systems of all types, and usable in 'missiles';

Note: 7A103.a.2. does not control equipment containing accelerometers specified in 7A001.a.1. or 7A001.a.2. where such accelerometers are specially designed and developed as MWD (Measurement While Drilling) sensors for use in down-hole well services operations

Technical Note:

'Inertial measurement equipment or systems' specified in 7A103.a. incorporate accelerometers or gyros to measure changes in velocity and orientation in order to determine or maintain heading or position without requiring an external reference once aligned.

Note: *'Inertial measurement equipment or systems' in 7A103.a. include:*

- *Attitude and Heading Reference Systems (AHRs);*
- *Gyrocompasses;*
- *Inertial Measurement Units (IMUs);*
- *Inertial Navigation Systems (INSs);*
- *Inertial Reference Systems (IRSs);*
- *Inertial Reference Units (IRUs).*

- b. Integrated flight instrument systems which include gyrostabilisers or automatic pilots, designed or modified for use in 'missiles';
- c. 'Integrated navigation systems', designed or modified for 'missiles' and capable of providing a navigational accuracy of 200 m 'CEP' or less;

Technical Notes:

1. *An 'integrated navigation system' typically incorporates the following components:*
 - a. *An inertial measurement device (e.g., an attitude and heading reference system, inertial reference unit, or inertial navigation system);*
 - b. *One or more external sensors used to update the position and/or velocity, either periodically or continuously throughout the flight (e.g., satellite navigation receiver, radar altimeter, and/or Doppler radar); and*
 - c. *Integration hardware and software;*
2. *In 7A103.c. 'CEP' (Circular Error Probable or Circle of Equal Probability) is a measure of accuracy, defined as the radius of the circle inside of which there is a 50% probability of being located.*

7A103 continued

- d. Three axis magnetic heading sensors, designed or modified to be integrated with flight control and navigation systems, other than those specified in 6A006, having all of the following characteristics, and specially designed components therefor:
 - 1. Internal tilt compensation in pitch (± 90 degrees) and roll (± 180 degrees) axes; and
 - 2. Azimuthal accuracy better (less) than 0,5 degrees rms at latitude of ± 80 degrees, reference to local magnetic field.

Note: Flight control and navigation systems in 7A103.d. include gyrostabilisers, automatic pilots and inertial navigation systems.

Technical Note:

In 7A103 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.

- 7A104 Gyro-astro compasses and other devices, other than those specified in 7A004, which derive position or orientation by means of automatically tracking celestial bodies or satellites and specially designed components therefor.

7A105 Receiving equipment for navigation satellite systems, other than those specified in 7A005, having any of the following characteristics, and specially designed components therefor:

- a. Designed or modified for use in space launch vehicles specified in 9A004, sounding rockets specified in 9A104 or unmanned aerial vehicles specified in 9A012 or 9A112.a.; or
- b. Designed or modified for airborne applications and having any of the following:
 - 1. Capable of providing navigation information at speeds in excess of 600 m/s;
 - 2. Employing decryption, designed or modified for military or governmental services, to gain access to a 'navigation satellite system' secured signal/data; or
 - 3. Being specially designed to employ anti-jam features (e.g., null steering antenna or electronically steerable antenna) to function in an environment of active or passive countermeasures.

Notes:

- 1. *7A105.b.2. and 7A105.b.3. do not control equipment designed for commercial, civil or Safety of Life (e.g., data integrity, flight safety) navigation satellite system services.*
- 2. *In 7A105, navigation satellite system include Global Navigation Satellite Systems (GNSS; e.g., GPS, GLONASS, Galileo or BeiDou) and Regional Navigation Satellite Systems (RNSS; e.g., NavIC, QZSS).*

7A106 Altimeters, other than those specified in 7A006, of radar or laser radar type, designed or modified for use in space launch vehicles specified in 9A004 or sounding rockets specified in 9A104.

7A115 Passive sensors for determining bearing to specific electromagnetic source (direction finding equipment) or terrain characteristics, designed or modified for use in space launch vehicles specified in 9A004 or sounding rockets specified in 9A104.

Note: Equipment specified in 7A105, 7A106, and 7A115 includes the following:

- a. Terrain contour mapping equipment;*
- b. Scene mapping and correlation (both digital and analogue) equipment;*
- c. Doppler navigation radar equipment;*
- d. Passive interferometer equipment;*
- e. Imaging sensor equipment (both active and passive).*

7A116 Flight control systems and servo valves, as follows; designed or modified for use in space launch vehicles specified in 9A004, sounding rockets specified in 9A104 or "missiles".

- a. Pneumatic, hydraulic, mechanical, electro-optical, or electro-mechanical flight control systems (including fly-by-wire and fly-by-light systems);
- b. Attitude control equipment;
- c. Flight control servo valves designed or modified for the systems specified in 7A116.a. or 7A116.b., and designed or modified to operate in a vibration environment greater than 10 g rms between 20 Hz and 2 kHz.

Note: For conversion of manned aircraft to operate as "missiles", 7A116 includes the systems, equipment and valves designed or modified to enable operation of manned aircraft as unmanned aerial vehicles.

7A117 "Guidance sets", usable in "missiles" capable of achieving system accuracy of 3,33% or less of the range (e.g., a 'CEP' of 10 km or less at a range of 300 km).

Technical Note:

In 7A117 'CEP' (Circular Error Probable or Circle of Equal Probability) is a measure of accuracy, defined as the radius of the circle centred at the target, at a specific range, in which 50% of the payloads impact.

7B Test, Inspection and Production Equipment

7B001 Test, calibration or alignment equipment, specially designed for equipment specified in 7A.

Note: 7B001 does not control test, calibration or alignment equipment for "Maintenance Level I" or "Maintenance Level II".

7B002 Equipment specially designed to characterize mirrors for ring "laser" gyros, as follows:

N.B. SEE ALSO 7B102.

- a. Scatterometers having a measurement "accuracy" of 10 ppm or less (better);
- b. Profilometers having a measurement "accuracy" of 0,5 nm (5 angstrom) or less (better).

7B003 Equipment specially designed for the "production" of equipment specified in 7A.

Note: 7B003 includes:

- Gyro tuning test stations;
- Gyro dynamic balance stations;
- Gyro run-in/motor test stations;
- Gyro evacuation and fill stations;
- Centrifuge fixtures for gyro bearings;
- Accelerometer axis align stations;
- Fibre optic gyro coil winding machines.

7B102 Reflectometers specially designed to characterise mirrors, for "laser" gyros, having a measurement accuracy of 50 ppm or less (better).

7B103 "Production facilities" and "production equipment" as follows:

- a. "Production facilities" specially designed for equipment specified in 7A117;
- b. "Production equipment", and other test, calibration and alignment equipment, other than that specified in 7B001 to 7B003, designed or modified to be used with equipment specified in 7A.

7C Materials

None.

7D Software

7D001 "Software" specially designed or modified for the "development" or "production" of equipment specified in 7A or 7B.

7D002 "Source code" for the operation or maintenance of any inertial navigation equipment, including inertial equipment not specified in 7A003 or 7A004, or Attitude and Heading Reference Systems ('AHRS').

Note: 7D002 does not control "source code" for the "use" of gimballed 'AHRS'.

Technical Note:

For the purposes of 7D002, 'AHRS' generally differ from Inertial Navigation Systems (INS) in that an 'AHRS' provides attitude and heading information and normally does not provide the acceleration, velocity and position information associated with an INS.

7D003 Other "software" as follows:

- a. "Software" specially designed or modified to improve the operational performance or reduce the navigational error of systems to the levels specified in 7A003, 7A004 or 7A008;
- b. "Source code" for hybrid integrated systems which improves the operational performance or reduces the navigational error of systems to the level specified in 7A003 or 7A008 by continuously combining heading data with any of the following:
 - 1. Doppler radar or sonar velocity data;
 - 2. "Satellite navigation system" reference data; or
 - 3. Data from "Data-Based Referenced Navigation" ("DBRN") systems;

7D003 continued

- c. Not used;
- d. Not used;
- e. Computer-Aided-Design (CAD) "software" specially designed for the "development" of "active flight control systems", helicopter multi-axis fly-by-wire or fly-by-light controllers or helicopter "circulation-controlled anti-torque or circulation-controlled direction control systems", whose "technology" is specified in 7E004.b.1., 7E004.b.3. to 7E004.b.5., 7E004.b.7., 7E004.b.8., 7E004.c.1. or 7E004.c.2.

7D004 "Source code" incorporating "development" "technology" specified in 7E004.a.2., 7E004.a.3., 7E004.a.5., 7E004.a.6. or 7E004.b., for any of the following:

- a. Digital flight management systems for "total control of flight";
- b. Integrated propulsion and flight control systems;
- c. "Fly-by-wire systems" or "fly-by-light systems";
- d. Fault-tolerant or self-reconfiguring "active flight control systems";
- e. Not used;
- f. Air data systems based on surface static data; or
- g. Three dimensional displays.

Note: 7D004. does not control "source code" associated with common computer elements and utilities (e.g., input signal acquisition, output signal transmission, computer "program" and data loading, built-in test, task scheduling mechanisms) not providing a specific flight control system function.

7D005 "Software" specially designed to decrypt "satellite navigation system" ranging code designed for government use.

7D101 "Software" specially designed or modified for the "use" of equipment specified in 7A001 to 7A006, 7A101 to 7A106, 7A115, 7A116.a., 7A116.b., 7B001, 7B002, 7B003, 7B102 or 7B103.

7D102 Integration "software" as follows:

- a. Integration "software" for the equipment specified in 7A103.b.;
- b. Integration "software" specially designed for the equipment specified in 7A003 or 7A103.a.;
- c. Integration "software" designed or modified for the equipment specified in 7A103.c.

Note: A common form of integration "software" employs Kalman filtering.

7D103 "Software" specially designed for modelling or simulation of the "guidance sets" specified in 7A117 or for their design integration with the space launch vehicles specified in 9A004 or sounding rockets specified in 9A104.

Note: "Software" specified in 7D103 remains controlled when combined with specially designed hardware specified in 4A102.

7D104 "Software" specially designed or modified for the operation or maintenance of "guidance sets" specified in 7A117.

Note: 7D104 includes "software", specially designed or modified to enhance the performance of "guidance sets" to achieve or exceed the accuracy specified in 7A117.

7E Technology

7E001 "Technology" according to the General Technology Note for the "development" of equipment or "software", specified in 7A, 7B, 7D001, 7D002, 7D003, 7D005 and 7D101 to 7D103.

Note: 7E001 includes key management "technology" exclusively for equipment specified in 7A005.a.

7E002 "Technology" according to the General Technology Note for the "production" of equipment specified in 7A or 7B.

7E003 "Technology" according to the General Technology Note for the repair, refurbishing or overhaul of equipment specified in 7A001 to 7A004.

Note: 7E003 does not control "technology" for maintenance, directly associated with calibration, removal or replacement of damaged or unserviceable LRUs and SRAs of a "civil aircraft" as described in "Maintenance Level I" or "Maintenance Level II".

7E004 Other "technology" as follows:

- a. "Technology" for the "development" or "production" of any of the following:
 - 1. Not used;
 - 2. Air data systems based on surface static data only, i.e., which dispense with conventional air data probes;
 - 3. Three dimensional displays for "aircraft";
 - 4. Not used;
 - 5. Electric actuators (i.e., electromechanical, electrohydrostatic and integrated actuator package) specially designed for 'primary flight control';

Technical Note:

For the purposes of 7E004.a.5., 'primary flight control' is "aircraft" stability or manoeuvring control using force/moment generators, i.e., aerodynamic control surfaces or propulsive thrust vectoring.

- 6. 'Flight control optical sensor array' specially designed for implementing "active flight control systems"; or

Technical Note:

For the purposes of 7E004.a.6., a 'flight control optical sensor array' is a network of distributed optical sensors, using "laser" beams, to provide real-time flight control data for on-board processing.

- 7. "DBRN" systems designed to navigate underwater, using sonar or gravity databases, that provide a positioning "accuracy" equal to or less (better) than 0,4 nautical miles;

- b. "Development" "technology", as follows, for "active flight control systems" (including "fly-by-wire systems" or "fly-by-light systems"):

- 1. Photonic-based "technology" for sensing "aircraft" or flight control component state, transferring flight control data, or commanding actuator movement, "required" for "fly-by-light systems" "active flight control systems";
- 2. Not used;
- 3. Real-time algorithms to analyse component sensor information to predict and preemptively mitigate impending degradation and failures of components within an "active flight control system";

Note: 7E004.b.3. does not control algorithms for purpose of off-line maintenance.

7E004.b. continued

4. Real-time algorithms to identify component failures and reconfigure force and moment controls to mitigate "active flight control system" degradations and failures;

Note: 7E004.b.4. does not control algorithms for the elimination of fault effects through comparison of redundant data sources, or off-line pre-planned responses to anticipated failures.

5. Integration of digital flight control, navigation and propulsion control data, into a digital flight management system for "total control of flight";

Note: 7E004.b.5. does not control:

- a. "Technology" for integration of digital flight control, navigation and propulsion control data, into a digital flight management system for 'flight path optimisation';
- b. "Technology" for "aircraft" flight instrument systems integrated solely for Very High Frequency Omni-directional Range (VOR), Distance Measuring Equipment (DME), Instrument Landing System (ILS) or Microwave Landing Systems (MLS) navigation or approaches.

Technical Note:

'Flight path optimisation' is a procedure that minimises deviations from a four-dimensional (space and time) desired trajectory based on maximising performance or effectiveness for mission tasks.

6. Not used;
7. "Technology" "required" for deriving the functional requirements for "fly-by-wire systems" having all of the following:
 - a. 'Inner-loop' airframe stability controls requiring loop closure rates of 40 Hz or greater; and

Technical Note:

For the purposes of 7E004.b.7.a., 'inner-loop' refers to functions of "active flight control systems" that automate airframe stability controls.

- b. Having any of the following:
 1. Corrects an aerodynamically unstable airframe, measured at any point in the design flight envelope, that would lose recoverable control if not corrected within 0,5 seconds;
 2. Couples controls in two or more axes while compensating for 'abnormal changes in aircraft state';

Technical Note:

For the purposes of 7E004.b.7.b.2., 'abnormal changes in aircraft state' include in-flight structural damage, loss of engine thrust, disabled control surface, or destabilising shifts in cargo load.

3. Performs the functions specified in 7E004.b.5.; or

Note: 7E004.b.7.b.3. does not control autopilots.

4. Enables "aircraft" to have stable controlled flight, other than during take-off or landing, at greater than 18 degrees angle of attack, 15 degrees side slip, 15 degrees/second pitch or yaw rate, or 90 degrees/second roll rate;
8. "Technology" "required" for deriving the functional requirements for "fly-by-wire systems" to achieve all of the following:
 - a. No loss of control of the "aircraft" in the event of a consecutive sequence of any two individual faults within the "fly-by-wire system"; and
 - b. Probability of loss of control of the "aircraft" being less (better) than 1×10^{-9} failures per flight hour;

Note: 7E004.b. does not control "technology" associated with common computer elements and utilities (e.g., input signal acquisition, output signal transmission, computer "program" and data loading, built-in test, task scheduling mechanisms) not providing a specific flight control system function.

7E004 continued

- c. "Technology" for the "development" of helicopter systems, as follows:
 - 1. Multi-axis fly-by-wire or fly-by-light controllers, which combine the functions of at least two of the following into one controlling element:
 - a. Collective controls;
 - b. Cyclic controls;
 - c. Yaw controls;
 - 2. "Circulation-controlled anti-torque or circulation-controlled direction control systems";
 - 3. Rotor blades incorporating 'variable geometry aerofoils', for use in systems using individual blade control.

Technical Note:

For the purposes of 7E004.c.3., 'variable geometry aerofoils' use trailing edge flaps or tabs, or leading edge slats or pivoted nose droop, the position of which can be controlled in flight.

- 7E101 "Technology" according to the General Technology Note for the "use" of equipment specified in 7A001 to 7A006, 7A101 to 7A106, 7A115 to 7A117, 7B001, 7B002, 7B003, 7B102, 7B103, 7D101 to 7D103.
- 7E102 "Technology" for protection of avionics and electrical subsystems against electromagnetic pulse (EMP) and electromagnetic interference (EMI) hazards, from external sources, as follows:
- a. Design "technology" for shielding systems;
 - b. Design "technology" for the configuration of hardened electrical circuits and subsystems;
 - c. Design "technology" for the determination of hardening criteria of 7E102.a. and 7E102.b.
- 7E104 "Technology" for the integration of the flight control, guidance, and propulsion data into a flight management system for optimisation of rocket system trajectory.

PART X – Category 8

CATEGORY 8 - MARINE

8A Systems, Equipment and Components

8A001 Submersible vehicles and surface vessels, as follows:

N.B. For the control status of equipment for submersible vehicles, see:

- Category 6 for sensors;
- Categories 7 and 8 for navigation equipment;
- Category 8A for underwater equipment.

- a. Manned, tethered submersible vehicles designed to operate at depths exceeding 1 000 m;
- b. Manned, untethered submersible vehicles having any of the following:
 1. Designed to 'operate autonomously' and having a lifting capacity of all of the following:
 - a. 10% or more of their weight in air; and
 - b. 15 kN or more;
 2. Designed to operate at depths exceeding 1 000 m; or
 3. Having all of the following:
 - a. Designed to continuously 'operate autonomously' for 10 hours or more; and
 - b. 'Range' of 25 nautical miles or more;

Technical Notes:

1. For the purposes of 8A001.b., 'operate autonomously' means fully submerged, without snorkel, all systems working and cruising at minimum speed at which the submersible can safely control its depth dynamically by using its depth planes only, with no need for a support vessel or support base on the surface, seabed or shore, and containing a propulsion system for submerged or surface use.
2. For the purposes of 8A001.b.3.b., 'range' means half the maximum distance a submersible vehicle can 'operate autonomously'.

8A001 continued

- c. Unmanned submersible vehicles, as follows:
 - 1. Unmanned submersible vehicles having any of the following:
 - a. Designed for deciding a course relative to any geographical reference without real-time human assistance; or
 - b. Acoustic data or command link;
 - c. Not used;
 - 2. Unmanned submersible vehicles, not specified in 8A001.c.1., having all of the following:
 - a. Designed to operate with a tether;
 - b. Designed to operate at depths exceeding 1 000 m;
 - c. Having any of the following:
 - 1. Designed for self-propelled manoeuvre using propulsion motors or thrusters specified in 8A002.a.2.; or
 - 2. Fibre optic data link;
- d. Not used;
- e. Ocean salvage systems with a lifting capacity exceeding 5 MN for salvaging objects from depths exceeding 250 m and having any of the following:
 - 1. Dynamic positioning systems capable of position keeping within 20 m of a given point provided by the navigation system; or
 - 2. Seafloor navigation and navigation integration systems, for depths exceeding 1 000 m and with positioning "accuracies" to within 10 m of a predetermined point;
- f. Not used;
- g. Not used;
- h. Not used;
- i. Not used.

8A002 Marine systems, equipment and components, as follows:

Note: *For underwater communications systems, see Category 5, Part 1 - Telecommunications.*

a. Systems, equipment and components, specially designed or modified for submersible vehicles and designed to operate at depths exceeding 1 000 m, as follows:

1. Pressure housings or pressure hulls with a maximum inside chamber diameter exceeding 1,5 m;
2. Direct current electric propulsion thrusters and specially designed motors therefor;

Technical Note:

For the purposes of 8A002.a.2., brushless direct current motors may be referred to as Permanent Magnet Alternating Current (PMAC) motors.

3. Umbilical cables, and connectors therefor, using optical fibre and having synthetic strength members;
4. Components manufactured from material specified in 8C001;

8A002 continued

- b. Systems specially designed or modified for the 'automated control' of the motion of submersible vehicles specified in 8A001, using navigation data, having closed loop servo-controls and having any of the following:
 - 1. Enabling a vehicle to move within 10 m of a predetermined point in the water column;
 - 2. Maintaining the position of the vehicle within 10 m of a predetermined point in the water column; or
 - 3. Maintaining the position of the vehicle within 10 m while following a cable on or under the seabed;

Technical Note:

For the purposes of 8A002.b., 'automated control' systems apply to systems onboard submersible vehicles.

- c. Fibre optic pressure hull penetrators;
- d. Not used;

8A002 continued

- e. Not used;
- f. Not used;
- g. Not used;
- h. "Robots" specially designed for underwater use, controlled by using a dedicated computer and having any of the following:
 - 1. Systems that control the "robot" using information from sensors which measure force or torque applied to an external object, distance to an external object, or tactile sense between the "robot" and an external object; or
 - 2. The ability to exert a force of 250 N or more or a torque of 250 Nm or more and using titanium based alloys or "composite" "fibrous or filamentary materials" in their structural members;

8A002 continued

- i. Remotely controlled articulated manipulators specially designed or modified for use with submersible vehicles and having any of the following:
 - 1. Systems which control the manipulator using information from sensors which measure any of the following:
 - a. Torque or force applied to an external object; or
 - b. Tactile sense between the manipulator and an external object; or
 - 2. Controlled by proportional master-slave techniques and having 5 degrees of 'freedom of movement' or more;

Technical Note:

For the purposes of 8A002.i.2., only functions having proportionally related motion control using positional feedback are counted when determining the number of degrees of 'freedom of movement'.

- j. Air independent power systems specially designed for underwater use, as follows:
 - 1. Brayton or Rankine cycle engine air independent power systems having any of the following:
 - a. Chemical scrubber or absorber systems, specially designed to remove carbon dioxide, carbon monoxide and particulates from recirculated engine exhaust;
 - b. Systems specially designed to use a monoatomic gas;
 - c. Devices or enclosures, specially designed for underwater noise reduction in frequencies below 10 kHz, or special mounting devices for shock mitigation; or
 - d. Systems having all of the following:
 - 1. Specially designed to pressurise the products of reaction or for fuel reformation;
 - 2. Specially designed to store the products of the reaction; and
 - 3. Specially designed to discharge the products of the reaction against a pressure of 100 kPa or more;

2. Diesel cycle engine air independent systems having all of the following:
 - a. Chemical scrubber or absorber systems, specially designed to remove carbon dioxide, carbon monoxide and particulates from recirculated engine exhaust;
 - b. Systems specially designed to use a monoatomic gas;
 - c. Devices or enclosures, specially designed for underwater noise reduction in frequencies below 10 kHz, or special mounting devices for shock mitigation; and
 - d. Specially designed exhaust systems that do not exhaust continuously the products of combustion;
3. "Fuel cell" air independent power systems with an output exceeding 2 kW and having any of the following:
 - a. Devices or enclosures, specially designed for underwater noise reduction in frequencies below 10 kHz, or special mounting devices for shock mitigation; or
 - b. Systems having all of the following:
 1. Specially designed to pressurise the products of reaction or for fuel reformation;
 2. Specially designed to store the products of the reaction; and
 3. Specially designed to discharge the products of the reaction against a pressure of 100 kPa or more;
4. Stirling cycle engine air independent power systems having all of the following:
 - a. Devices or enclosures, specially designed for underwater noise reduction in frequencies below 10 kHz, or special mounting devices for shock mitigation; and
 - b. Specially designed exhaust systems which discharge the products of combustion against a pressure of 100 kPa or more;

8A002 continued

- k. Not used;
- l. Not used;
- m. Not used;
- n. Not used;
- o. Propellers, power transmission systems, power generation systems and noise reduction systems and related equipment, as follows:
 - 1. Not used;
 - 2. Water-screw propeller, power generation systems or transmission systems, designed for use on vessels, as follows:
 - a. Controllable-pitch propellers and hub assemblies, rated at more than 30 MW;
 - b. Internally liquid-cooled electric propulsion motors with a power output exceeding 2,5 MW;
 - c. "Superconductive" propulsion motors, with a power output exceeding 0,1 MW;
 - d. Power transmission systems incorporating "composite" shafts and designed to transmit power exceeding 10 MW;
 - e. Ventilated or base-ventilated propeller systems, rated at more than 2,5 MW;

8A002.o. continued

3. Noise reduction systems and related equipment, designed for use on vessels of 1 000 tonnes displacement or more, as follows:
 - a. Systems that attenuate underwater noise at frequencies below 500 Hz and consist of compound acoustic mounts for the acoustic isolation of diesel engines, diesel generator sets, gas turbines, gas turbine generator sets, propulsion motors or propulsion reduction gears, specially designed for sound or vibration isolation and having an intermediate mass exceeding 30% of the equipment to be mounted;
 - b. 'Active noise reduction or cancellation systems' or magnetic bearings, specially designed for power transmission systems;

Technical Note:

For the purposes of 8A002.o.3.b., 'active noise reduction or cancellation systems' incorporate electronic control systems capable of actively reducing equipment vibration by the generation of anti-noise or anti-vibration signals directly to the source.

4. Permanent magnet electric propulsion motors specially designed for submersible vehicles, having a power output exceeding 0,1 MW.

Note: 8A002.o.4. includes rim-driven propulsion systems.

8A002 continued

- p. Pumpjet propulsion systems having all of the following:
 - 1. Power output exceeding 2,5 MW; and
 - 2. Using divergent nozzle and flow conditioning vane techniques to improve propulsive efficiency or reduce propulsion-generated underwater-radiated noise;
- q. Underwater swimming and diving equipment as follows:
 - 1. Closed circuit rebreathers;
 - 2. Semi-closed circuit rebreathers;

Note: 8A002.q. does not control individual rebreathers for personal use when accompanying their users.

N.B. For equipment and devices specially designed for military use, SEE THE MILITARY GOODS CONTROLS.

- r. Diver deterrent acoustic systems specially designed or modified to disrupt divers and having a sound pressure level equal to or exceeding 190 dB (reference 1 μ Pa at 1 m) at frequencies of 200 Hz and below.

Note 1: 8A002.r. does not control diver deterrent systems based on underwater explosive devices, air guns or combustible sources.

Note 2: 8A002.r. includes diver deterrent acoustic systems that use spark gap sources, also known as plasma sound sources.

8B Test, Inspection and Production Equipment

- 8B001 Water tunnels designed to have a background noise of less than 100 dB (reference 1 μ Pa, 1 Hz) within the frequency range exceeding 0 Hz but not exceeding 500 Hz and designed for measuring acoustic fields generated by a hydro-flow around propulsion system models.

8C Materials

- 8C001 'Syntactic foam' designed for underwater use and having all of the following:

N.B. See also 8A002.a.4.

- a. Designed for marine depths exceeding 1 000 m; and
- b. A density less than 561 kg/m³.

Technical Note:

For the purposes of 8C001, 'syntactic foam' consists of hollow spheres of plastic or glass embedded in a resin "matrix".

8D Software

- 8D001 "Software" specially designed or modified for the "development", "production" or "use" of equipment or materials, specified in 8A, 8B or 8C.
- 8D002 Specific "software" specially designed or modified for the "development", "production", repair, overhaul or refurbishing (re-machining) of propellers specially designed for underwater noise reduction.

8E Technology

- 8E001 "Technology" according to the General Technology Note for the "development" or "production" of equipment or materials, specified in 8A, 8B or 8C.
- 8E002 Other "technology" as follows:
- a. "Technology" for the "development", "production", repair, overhaul or refurbishing (re-machining) of propellers specially designed for underwater noise reduction;
 - b. "Technology" for the overhaul or refurbishing of equipment specified in 8A001, 8A002.b., 8A002.j., 8A002.o. or 8A002.p.;
 - c. "Technology" according to the General Technology Note for the "development" or "production" of any of the following:

8E002.c. continued

1. Surface-effect vehicles (fully skirted variety) having all of the following:
 - a. Maximum design speed, fully loaded, exceeding 30 knots in a significant wave height of 1,25 m or more;
 - b. Cushion pressure exceeding 3 830 Pa; and
 - c. Light-ship-to-full-load displacement ratio of less than 0,70;
2. Surface-effect vehicles (rigid sidewalls) with a maximum design speed, fully loaded, exceeding 40 knots in a significant wave height of 3,25 m or more;
3. Hydrofoil vessels with active systems for automatically controlling foil systems, with a maximum design speed, fully loaded, of 40 knots or more in a significant wave height of 3,25 m or more; or
4. 'Small waterplane area vessels' having any of the following:
 - a. Full load displacement exceeding 500 tonnes with a maximum design speed, fully loaded, exceeding 35 knots in a significant wave height of 3,25 m or more; or
 - b. Full load displacement exceeding 1 500 tonnes with a maximum design speed, fully loaded, exceeding 25 knots in a significant wave height of 4 m or more.

Technical Note:

For the purposes of 8E002.c.4., a 'small waterplane area vessel' is defined by the following formula: waterplane area at an operational design draft less than $2 \times (\text{displaced volume at the operational design draft})^{2/3}$.

PART XI – Category 9

CATEGORY 9 – AEROSPACE AND PROPULSION

9A Systems, Equipment and Components

N.B. For propulsion systems designed or rated against neutron or transient ionising radiation, SEE THE MILITARY GOODS CONTROLS.

9A001 Aero gas turbine engines having any of the following:

N.B. SEE ALSO 9A101.

- a. Incorporating any of the "technologies" specified in 9E003.a., 9E003.h. or 9E003.i.

Note 1: 9A001 does not control aero gas turbine engines which meet all of the following:

- a. Certified by the civil aviation authorities of one or more EU Member States or Wassenaar Arrangement Participating States; and
- b. Intended to power non-military manned "aircraft" for which any of the following has been issued by civil aviation authorities of one or more Member States or Wassenaar Arrangement Participating States for the "aircraft" with this specific engine type:
1. A civil type certificate; or
 2. An equivalent document recognised by the International Civil Aviation Organization (ICAO).

Note 2: 9A001 does not control aero gas turbine engines designed for Auxiliary Power Units (APUs) approved by the civil aviation authority in a Member States or Wassenaar Arrangement Participating States.

- b. Not used.

9A002 'Marine gas turbine engines' designed to use liquid fuel and having all of the following, and specially designed assemblies and components therefor:

- a. Maximum continuous power when operating in "steady state mode" at standard reference conditions specified in ISO 3977-2:1997 (or national equivalent) of 24 245 kW or more; and
- b. 'Corrected specific fuel consumption' not exceeding 0,219 kg/kWh at 35% of the maximum continuous power when using liquid fuel.

Note: The term 'marine gas turbine engines' includes those industrial, or aero-derivative, gas turbine engines adapted for a ship's electric power generation or propulsion.

Technical Note:

For the purposes of 9A002, 'corrected specific fuel consumption' is the specific fuel consumption of the engine corrected to a marine distillate liquid fuel having a net specific energy (i.e. net heating value) of 42MJ/kg (ISO 3977-2:1997).

9A003 Specially designed assemblies or components, incorporating any of the "technologies" specified in 9E003.a., 9E003.h. 9E003.i., or 9E003.k, for any of the following aero gas turbine engines:

- a. Specified in 9A001; or
- b. Whose design or production origins are either non-EU Member States or Wassenaar Arrangement Participating States or unknown to the manufacturer.

9A004 Space launch vehicles, "spacecraft", "spacecraft buses", "spacecraft mission equipment", "spacecraft" on-board systems or equipment, terrestrial equipment, air-launch platforms and "sub-orbital craft" as follows:

N.B. SEE ALSO 9A104.

a. Space launch vehicles;

b. "Spacecraft";

N.B. For "sub-orbital craft", see 9A004.h.

c. "Spacecraft buses";

d. "Spacecraft mission equipment" incorporating items specified in 3A001.b.1.a.4., 3A002.g., 5A001.a.1., 5A001.b.3., 5A002.c., 5A002.e., 6A002.a.1., 6A002.a.2., 6A002.b., 6A002.d., 6A003.b., 6A004.c., 6A004.e., 6A008.d., 6A008.e., 6A008.k., 6A008.l. or 9A010.c.;

e. On-board systems or equipment, specially designed for "spacecraft" and having any of the following functions:

1. Command and telemetry data handling;

Note: 9A004.e.1. includes bus data management, storage, and processing.

2. Payload data handling; or

Note: 9A004.e.2. includes management, storage, and processing of "spacecraft mission equipment" data.

3. Attitude and orbit control;

Note: 9A004.e.3 includes sensing and actuation to determine and control the position and orientation of a "spacecraft".

N.B. For equipment specially designed for military use, SEE MILITARY GOODS CONTROLS.

9A004 continued

- f. Terrestrial equipment specially designed for "spacecraft", as follows:
 - 1. Telemetry and telecommand equipment specially designed for any of the following data processing functions:
 - a. Telemetry data processing of frame synchronisation and error corrections, for monitoring of operational status (also known as health and safe status) of the "spacecraft bus"; or
 - b. Command data processing for formatting command data being sent to the "spacecraft" to control the "spacecraft bus";
 - 2. Simulators specially designed for 'verification of operational procedures' of "spacecraft";

Technical Note:

For the purposes of 9A004.f.2., 'verification of operational procedures' is any of the following:

- 1. *Command sequence confirmation;*
 - 2. *Operational training;*
 - 3. *Operational rehearsals; or*
 - 4. *Operational analysis.*
 - g. "Aircraft" specially designed or modified to be air-launch platforms for space launch vehicles or "sub-orbital craft";
 - h. "Sub-orbital craft".

9A005 Liquid rocket propulsion systems containing any of the systems or components, specified in 9A006.

N.B. SEE ALSO 9A105 AND 9A119.

9A006 Systems and components, specially designed for liquid rocket propulsion systems, as follows:

N.B. SEE ALSO 9A106, 9A108 AND 9A120.

- a. Cryogenic refrigerators, flightweight dewars, cryogenic heat pipes or cryogenic systems, designed to restrict cryogenic fluid losses to less than 30% per year;
- b. Cryogenic containers or closed-cycle refrigeration systems, designed to maintain or produce temperatures less than or equal to 100 K (-173,15°C);
- c. Slush hydrogen storage or transfer systems;
- d. High pressure (exceeding 17,5 MPa) turbo pumps, pump components or their associated gas generator or expander cycle turbine drive systems;
- e. High-pressure (exceeding 10,6 MPa) thrust chambers and nozzles therefor;
- f. Propellant storage systems using the principle of capillary containment or positive expulsion (i.e., with flexible bladders);
- g. Liquid propellant injectors with individual orifices of 0,381 mm or smaller in diameter (an area of $1,14 \times 10^{-3} \text{ cm}^2$ or smaller for non-circular orifices) and specially designed for liquid rocket engines;
- h. One-piece carbon-carbon thrust chambers or one-piece carbon-carbon exit cones, with densities exceeding $1,4 \text{ g/cm}^3$ and tensile strengths exceeding 48 MPa.

9A007 Solid rocket propulsion systems having any of the following:

N.B. SEE ALSO 9A107 AND 9A119.

- a. Total impulse capacity exceeding 1,1 MNs;
- b. Specific impulse of 2,4 kNs/kg or more, when the nozzle flow is expanded to ambient sea level conditions for an adjusted chamber pressure of 7 MPa;
- c. Stage mass fractions exceeding 88% and propellant solid loadings exceeding 86%;
- d. Components specified in 9A008; or
- e. Insulation and propellant bonding systems, using direct-bonded motor designs to provide a "strong mechanical bond" or a barrier to chemical migration between the solid propellant and case insulation material.

9A008 Components specially designed for solid rocket propulsion systems, as follows:

N.B. SEE ALSO 9A108.

- a. Insulation and propellant bonding systems, using liners to provide a "strong mechanical bond" or a barrier to chemical migration between the solid propellant and case insulation material;
- b. Filament-wound "composite" motor cases exceeding 0,61 m in diameter or having 'structural efficiency ratios (PV/W)' exceeding 25 km;

Technical Note:

For the purposes of 9A008.b., 'structural efficiency ratio (PV/W)' is the burst pressure (P) multiplied by the vessel volume (V) divided by the total pressure vessel weight (W).

- c. Nozzles with thrust levels exceeding 45 kN or nozzle throat erosion rates of less than 0,075 mm/s;
- d. Movable nozzle or secondary fluid injection thrust vector control systems, capable of any of the following:
 - 1. Omni-axial movement exceeding $\pm 5^\circ$;
 - 2. Angular vector rotations of $20^\circ/\text{s}$ or more; or
 - 3. Angular vector accelerations of $40^\circ/\text{s}^2$ or more.

9A009 Hybrid rocket propulsion systems having any of the following:

N.B. SEE ALSO 9A109 AND 9A119.

- a. Total impulse capacity exceeding 1,1 MNs; or
- b. Thrust levels exceeding 220 kN in vacuum exit conditions.

9A010 Specially designed components, systems and structures, for launch vehicles, launch vehicle propulsion systems or "spacecraft", as follows:

N.B. SEE ALSO 1A002 AND 9A110.

- a. Components and structures, each exceeding 10 kg and specially designed for launch vehicles manufactured using any of the following:
 - 1. "Composite" materials consisting of "fibrous or filamentary materials" specified in 1C010.e. and resins specified in 1C008 or 1C009.b.;
 - 2. Metal "matrix" "composites" reinforced by any of the following:
 - a. Materials specified in 1C007 or 1C507;
 - b. "Fibrous or filamentary materials" specified in 1C010; or
 - c. Aluminides specified in 1C002.a.; or
 - 3. Ceramic "matrix" "composite" materials specified in 1C007 or 1C507;

Note: The weight cut-off is not relevant for nose cones.
- b. Components and structures, specially designed for launch vehicle propulsion systems specified in 9A005 to 9A009 manufactured using any of the following:
 - 1. "Fibrous or filamentary materials" specified in 1C010.e. and resins specified in 1C008 or 1C009.b.;
 - 2. Metal "matrix" "composites" reinforced by any of the following:
 - a. Materials specified in 1C007 or 1C507;
 - b. "Fibrous or filamentary materials" specified in 1C010; or
 - c. Aluminides specified in 1C002.a.; or
 - 3. Ceramic "matrix" "composite" materials specified in 1C007 or 1C507;
- c. Structural components and isolation systems, specially designed to control actively the dynamic response or distortion of "spacecraft" structures;
- d. Pulsed liquid rocket engines with thrust-to-weight ratios equal to or more than 1 kN/kg and a 'response time' of less than 30 ms.

Technical Note:

For the purposes of 9A010.d., 'response time' is the time required to achieve 90% of total rated thrust from start-up.

9A011 Ramjet, scramjet or 'combined cycle engines', and specially designed components therefor.

N.B. SEE ALSO 9A111 AND 9A118.

Technical Note:

For the purposes of 9A011, 'combined cycle engines' combine two or more of the following types of engines:

- Gas turbine engine (turbojet, turboprop and turbofan);
- Ramjet or scramjet;
- Rocket motor or engine (liquid/gel/solid-propellant and hybrid).

9A012 "Unmanned aerial vehicles" ("UAVs"), unmanned "airships", related equipment and components, as follows:

N.B.1. SEE ALSO 9A112.

N.B.2. For "UAVs" that are "sub-orbital craft", see 9A004.h.

a. "UAVs" or unmanned "airships", designed to have controlled flight out of the direct 'natural vision' of the 'operator' and having any of the following:

1. Having all of the following:
 - a. A maximum 'endurance' greater than or equal to 30 minutes but less than 1 hour; and
 - b. Designed to take-off and have stable controlled flight in wind gusts equal to or exceeding 46,3 km/h (25 knots); or
2. A maximum 'endurance' of 1 hour or greater;

Technical Notes:

For the purposes of 9A012.a.:

1. 'Operator' is a person who initiates or commands the "UAV" or unmanned "airship" flight.
2. 'Endurance' is to be calculated for International Standard Atmosphere (ISA) conditions (ISO 2533:1975) at sea level in zero wind.
3. 'Natural vision' means unaided human sight, with or without corrective lenses.

9A012 continued

- b. Related equipment and components, as follows:
 - 1. Not used;
 - 2. Not used;
 - 3. Equipment or components, specially designed to convert a manned "aircraft" or manned "airship", to a "UAV" or unmanned "airship", specified in 9A012.a.;
 - 4. Air breathing reciprocating or rotary internal combustion type engines, specially designed or modified to propel "UAVs" or unmanned "airships", at altitudes above 15 240 metres (50 000 feet).

9A101 Turbojet and turbofan engines, other than those specified in 9A001, as follows;

- a. Engines having all of the following characteristics:
 - 1. 'Maximum thrust value' greater than 400 N excluding civil certified engines with a 'maximum thrust value' greater than 8 890 N;
 - 2. Specific fuel consumption of 0,15 kg N⁻¹ h⁻¹ or less;
 - 3. 'Dry weight' less than 750 kg; and
 - 4. 'First-stage rotor diameter' less than 1 m;

Technical Notes:

- 1. *For the purpose of 9A101.a.1., 'maximum thrust value' is the manufacturer's demonstrated maximum thrust for the engine type un-installed at sea level static conditions using the ICAO standard atmosphere. The civil type certified thrust value will be equal to or less than the manufacturer's demonstrated maximum thrust for the engine type un-installed.*
 - 2. *Specific fuel consumption is determined at maximum continuous thrust for engine type un-installed at sea level static conditions using the ICAO standard atmosphere.*
 - 3. *'Dry weight' is the weight of the engine without fluids (fuel, hydraulic fluid, oil, etc.) and does not include the nacelle (housing).*
 - 4. *'First-stage rotor diameter' is the diameter of the first rotating stage of the engine, whether a fan or compressor, measured at the leading edge of the blade tips.*
- b. Engines designed or modified for use in "missiles" or unmanned aerial vehicles specified in 9A012 or 9A112.a.

9A102 'Turboprop engine systems' specially designed for unmanned aerial vehicles specified in 9A012 or 9A112.a., and specially designed components therefor, having a 'maximum power' greater than 10 kW.

Note: 9A102 does not control civil certified engines.

Technical Notes:

1. *For the purposes of 9A102, a 'turboprop engine system' incorporates all of the following:*
 - a. *Turboshaft engine; and*
 - b. *Power transmission system to transfer the power to a propeller.*
2. *For the purposes of 9A102, the 'maximum power' is achieved un-installed at sea level static conditions using ICAO standard atmosphere.*

9A104 Sounding rockets, capable of a range of at least 300 km.

N.B. SEE ALSO 9A004.

9A105 Liquid propellant rocket engines or gel propellant rocket motors, as follows:

N.B. SEE ALSO 9A119.

- a. Liquid propellant rocket engines or gel propellant rocket motors, usable in "missiles", other than those specified in 9A005, integrated, or designed or modified to be integrated, into a liquid propellant or gel propellant propulsion system which has a total impulse capacity equal to or greater than 1,1 MNs;
- b. Liquid propellant rocket engines or gel propellant rocket motors, usable in complete rocket systems or unmanned aerial vehicles, capable of a range of 300 km, other than those specified in 9A005 or 9A105.a., integrated, or designed or modified to be integrated, into a liquid propellant or gel propellant propulsion system which has a total impulse capacity equal to or greater than 0,841 MNs.

9A106 Systems or components, other than those specified in 9A006 as follows, specially designed for liquid rocket propulsion or gel propellant rocket systems:

- a. Not used;
- b. Not used;
- c. Thrust vector control sub-systems, usable in "missiles";

Technical Note:

Examples of methods of achieving thrust vector control specified in 9A106.c. are:

- 1. *Flexible nozzle;*
- 2. *Fluid or secondary gas injection;*
- 3. *Movable engine or nozzle;*
- 4. *Deflection of exhaust gas stream (jet vanes or probes); or*
- 5. *Thrust tabs.*

9A106 continued

- d. Liquid, slurry and gel propellant (including oxidisers) control systems, and specially designed components therefor, usable in "missiles", designed or modified to operate in vibration environments greater than 10 g rms between 20 Hz and 2 kHz;

Note: The only servo valves, pumps and gas turbines specified in 9A106.d., are the following:

- a. Servo valves designed for flow rates equal to or greater than 24 litres per minute, at an absolute pressure equal to or greater than 7 MPa, that have an actuator response time of less than 100 ms;*
- b. Pumps, for liquid propellants, with shaft speeds equal to or greater than 8 000 r.p.m. at a maximum operating mode or with discharge pressures equal to or greater than 7 MPa;*
- c. Gas turbines, for liquid propellant turbopumps, with shaft speeds equal to or greater than 8 000 r.p.m. at the maximum operating mode.*
- e. Combustion chambers and nozzles for liquid propellant rocket engines or gel propellant rocket motors specified in 9A005 or 9A105.

9A107 Solid propellant rocket motors, usable in complete rocket systems or unmanned aerial vehicles, capable of a range of 300 km, other than those specified in 9A007, having total impulse capacity equal to or greater than 0,841 MNs.

N.B. SEE ALSO 9A119.

9A108 Components, other than those specified in 9A008, as follows, specially designed for solid and hybrid rocket propulsion systems:

- a. Rocket motor cases and insulation components therefor, usable in subsystems specified in 9A007, 9A009, 9A107 or 9A109.a.;

N.B. For insulation material in bulk or sheet form, SEE ALSO 9C108.

Note:

In 9A108, insulation intended to be applied to the components of a rocket motor, i.e. the case, nozzle inlets, case closures, includes cured or semi-cured compounded rubber components comprising sheet stock containing an insulating or refractory material. It may also be incorporated as stress relief boots or flaps.

- b. Rocket nozzles, usable in subsystems specified in 9A007, 9A009, 9A107 or 9A109.a.;
- c. Thrust vector control sub-systems, usable in "missiles".

Technical Note:

Examples of methods of achieving thrust vector control specified in 9A108.c. are:

1. *Flexible nozzle;*
2. *Fluid or secondary gas injection;*
3. *Movable engine or nozzle;*
4. *Deflection of exhaust gas stream (jet vanes or probes); or*
5. *Thrust tabs.*

9A109 Hybrid rocket motors and specially designed components as follows:

- a. Hybrid rocket motors usable in complete rocket systems or unmanned aerial vehicles, capable of 300 km, other than those specified in 9A009, having a total impulse capacity equal to or greater than 0,841 MNs, and specially designed components therefor;
- b. Specially designed components for hybrid rocket motors specified in 9A009 that are usable in "missiles".

N.B. SEE ALSO 9A009 AND 9A119.

9A110 Composite structures, laminates and manufactures thereof, other than those specified in 9A010, specially designed for use in 'missiles' or the subsystems specified in 9A005, 9A007, 9A105, 9A106.c., 9A107, 9A108.c., 9A116 or 9A119.

N.B. SEE ALSO 1A002.

Technical Note:

In 9A110 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.

9A111 Pulse jet or detonation engines, usable in "missiles" or unmanned aerial vehicles specified in 9A012 or 9A112.a., and specially designed components therefor.

N.B. SEE ALSO 9A011 AND 9A118.

Technical Note:

In 9A111 detonation engines utilise detonation to produce a rise in effective pressure across the combustion chamber. Examples of detonation engines include pulse detonation engines, rotating detonation engines or continuous wave detonation engines.

9A112 "Unmanned aerial vehicles" ("UAVs"), other than those specified in 9A012, as follows:

- a. "Unmanned aerial vehicles" ("UAVs") capable of a range of 300 km;
- b. "Unmanned aerial vehicles" ("UAVs") having all of the following:
 - 1. Having any of the following:
 - a. An autonomous flight control and navigation capability; or
 - b. Capability of controlled flight out of the direct vision range involving a human operator; and
 - 2. Having any of the following:
 - a. Incorporating an aerosol dispensing system/mechanism with a capacity greater than 20 litres; or
 - b. Designed or modified to incorporate an aerosol dispensing system/mechanism with a capacity greater than 20 litres.

9A112.b. continued

Technical Notes:

1. *An aerosol consists of particulate or liquids other than fuel components, by products or additives, as part of the payload to be dispersed in the atmosphere. Examples of aerosols include pesticides for crop dusting and dry chemicals for cloud seeding.*
2. *An aerosol dispensing system/mechanism contains all those devices (mechanical, electrical, hydraulic, etc.), which are necessary for storage and dispersion of an aerosol into the atmosphere. This includes the possibility of aerosol injection into the combustion exhaust vapour and into the propeller slip stream.*

9A115 Launch support equipment as follows:

- a. Apparatus and devices for handling, control, activation or launching, designed or modified for space launch vehicles specified in 9A004, sounding rockets specified in 9A104 or 'missiles';

Technical Notes:

1. *In 9A115.a 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.*
2. *Apparatus and devices specified in 9A115.a include those installed on a manned aircraft or an unmanned aerial vehicle.*
- b. Vehicles for transport, handling, control, activation or launching, designed or modified for space launch vehicles specified in 9A004, sounding rockets specified in 9A104 or "missiles".

9A116 Reentry vehicles, usable in "missiles", and equipment designed or modified therefor, as follows:

- a. Reentry vehicles;
- b. Heat shields and components therefor, fabricated of ceramic or ablative materials;
- c. Heat sinks and components therefor, fabricated of light-weight, high heat capacity materials;
- d. Electronic equipment specially designed for reentry vehicles.

- 9A117 Staging mechanisms, separation mechanisms, and interstages, usable in "missiles".
N.B. SEE ALSO 9A121.
- 9A118 Devices to regulate combustion usable in engines, which are usable in "missiles" or unmanned aerial vehicles specified in 9A012 or 9A112.a., specified in 9A011 or 9A111.
- 9A119 Individual rocket stages, usable in complete rocket systems or unmanned aerial vehicles, capable of a range of 300 km, other than those specified in 9A005, 9A007, 9A009, 9A105, 9A107 and 9A109.
- 9A120 Liquid or gel propellant tanks, other than those specified in 9A006, specially designed for propellants specified in 1C111 or 'other liquid or gel propellants' used in rocket systems capable of delivering at least a 500 kg payload to a range of at least 300 km.
Note: In 9A120 'other liquid or gel propellants' includes, but is not limited to, propellants specified in THE MILITARY GOODS CONTROLS.
- 9A121 Umbilical and interstage electrical connectors specially designed for "missiles", space launch vehicles specified in 9A004 or sounding rockets specified in 9A104.
*Note:
In 9A121, interstage electrical connectors also include electrical connectors installed between the "missile", space launch vehicle or sounding rocket and their payload.*
- 9A350 Spraying or fogging systems, specially designed or modified for fitting to aircraft, "lighter-than-air vehicles" or unmanned aerial vehicles, and specially designed components therefor, as follows:
- a. Complete spraying or fogging systems capable of delivering, from a liquid suspension, an initial droplet 'VMD' of less than 50 µm at a flow rate of greater than two litres per minute;
 - b. Spray booms or arrays of aerosol generating units capable of delivering, from a liquid suspension, an initial droplet 'VMD' of less than 50 µm at a flow rate of greater than two litres per minute;
 - c. Aerosol generating units specially designed for fitting to systems specified in 9A350.a. and .b.

9A350.c. continued

Note: *Aerosol generating units are devices specially designed or modified for fitting to aircraft such as nozzles, rotary drum atomisers and similar devices.*

Note: *9A350 does not control spraying or fogging systems and components that are demonstrated not to be capable of delivering biological agents in the form of infectious aerosols.*

Technical Notes:

1. *Droplet size for spray equipment or nozzles specially designed for use on aircraft, "lighter-than-air vehicles" or unmanned aerial vehicles should be measured using either of the following:*
 - a. *Doppler laser method;*
 - b. *Forward laser diffraction method.*
2. *In 9A350 'VMD' means Volume Median Diameter and for water-based systems this equates to Mass Median Diameter (MMD).*

9B Test, Inspection and Production Equipment

Note 9B includes test, inspection and production equipment applicable to aero, aero-derivative, industrial or marine gas turbine engines.

9B001 Manufacturing equipment, tooling or fixtures, as follows:

N.B. SEE ALSO 2B226

- a. Directional-solidification or single-crystal casting equipment designed for "superalloys";
- b. Casting tooling, specially designed for manufacturing gas turbine engine blades, vanes or "tip shrouds", manufactured from refractory metals or ceramics, as follows:
 - 1. Cores;
 - 2. Shells (moulds);
 - 3. Combined core and shell (mould) units;
- c. Directional-solidification or single-crystal additive-manufacturing equipment, designed for "superalloys".

9B002 On-line (real time) control systems, instrumentation (including sensors) or automated data acquisition and processing equipment, having all of the following:

- a. Specially designed for the "development" of gas turbine engines, assemblies or components; and
- b. Incorporating any of the "technologies" specified in 9E003.h. or 9E003.i.

9B003 Equipment specially designed for the "production" or test of gas turbine engine brush seals designed to operate at tip speeds exceeding 335 m/s and temperatures in excess of 773 K (500°C), and specially designed components or accessories therefor.

9B004 Tools, dies or fixtures, for the solid-state joining of "superalloy", titanium or intermetallic aerofoil-to-disk combinations described in 9E003.a.3. or 9E003.a.6. for gas turbine engines.

9B005 On-line (real time) control systems, instrumentation (including sensors) or automated data acquisition and processing equipment, specially designed for use with any of the following:

N.B. SEE ALSO 9B105.

a. Wind tunnels designed for speeds of Mach 1,2 or more;

Note: 9B005.a. does not apply to wind tunnels specially designed for educational purposes and having a 'test section size' (measured laterally) of less than 250 mm.

Technical Note:

For the purposes of 9B005.a. Note, 'test section size' means the diameter of the circle, or the side of the square, or the longest side of the rectangle, at the largest test section location.

b. Devices for simulating flow-environments at speeds exceeding Mach 5, including hot-shot tunnels, plasma arc tunnels, shock tubes, shock tunnels, gas tunnels and light gas guns; or

c. Wind tunnels or devices, other than two-dimensional sections, capable of simulating Reynolds number flows exceeding 25×10^6 .

9B006 Acoustic vibration test equipment capable of producing sound pressure levels of 160 dB or more (referenced to 20 μ Pa) with a rated output of 4 kW or more at a test cell temperature exceeding 1 273 K (1 000°C), and specially designed quartz heaters therefor.

N.B. SEE ALSO 9B106.

- 9B007 Equipment specially designed for inspecting the integrity of rocket motors and using Non-Destructive Test (NDT) techniques other than planar x-ray or basic physical or chemical analysis.
- 9B008 Direct measurement wall skin friction transducers specially designed to operate at a test flow total (stagnation) temperature exceeding 833 K (560°C).
- 9B009 Tooling specially designed for producing gas turbine engine powder metallurgy rotor components having all of the following:
- a. Designed to operate at stress levels of 60% of ultimate tensile strength or more measured at a temperature of 873 K (600°C); and
 - b. Designed to operate at 873 K (600°C) or more.

Note: 9B009 does not control tooling for the "production" of powder.

- 9B010 Equipment specially designed for the "production" of items specified in 9A012.
- 9B105 Aerodynamic test facilities for speeds of Mach 0,9 or more, usable for 'missiles' and their subsystems.

N.B. SEE ALSO 9B005.

Notes:

1. *9B105 includes wind tunnels and shock tunnels for the study of airflow over objects.*
2. *9B105 does not control wind-tunnels for speeds of Mach 3 or less with dimension of the 'test cross section size' equal to or less than 250 mm.*

Technical Notes:

1. *In Note to 9B105, 'test cross section size' means the diameter of the circle, or the side of the square, or the longest side of the rectangle, or the major axis of the ellipse at the largest 'test cross section' location. 'Test cross section' is the section perpendicular to the flow direction.*
2. *In 9B105 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.*

9B106 Environmental chambers and anechoic chambers, as follows:

- a. Environmental chambers having all of the following:
 - 1. Capable of simulating any of the following flight conditions:
 - a. Altitude equal to or greater than 15 km; or
 - b. Temperature range from below 223 K (-50°C) to above 398 K (125°C); and
 - 2. Incorporating, or 'designed or modified' to incorporate, a shaker unit or other vibration test equipment to produce vibration environments equal to or greater than 10 g rms, measured 'bare table', between 20 Hz and 2 kHz while imparting forces equal to or greater than 5 kN;

Technical Notes:

- 1. 9B106.a.2. describes systems that are capable of generating a vibration environment with a single wave (e.g., a sine wave) and systems capable of generating a broad band random vibration (i.e., power spectrum).
- 2. In 9B106.a.2., 'designed or modified' means the environmental chamber provides appropriate interfaces (e.g., sealing devices) to incorporate a shaker unit or other vibration test equipment as specified in 2B116.
- 3. In 9B106.a.2., 'bare table' means a flat table, or surface, with no fixture or fittings.

- b. Environmental chambers capable of simulating the following flight conditions:
 - 1. Acoustic environments at an overall sound pressure level of 140 dB or greater (referenced to 20 µPa) or with a total rated acoustic power output of 4 kW or greater; and
 - 2. Altitude equal to or greater than 15 km; or
 - 3. Temperature range from below 223 K (-50°C) to above 398 K (125°C).

9B107 Aerothermodynamic test facilities, usable for 'missiles', 'missile' rocket propulsion systems, and reentry vehicles and equipment specified in 9A116, having any of the following characteristics:

- a. An electrical power supply equal to or greater than 5 MW; or
- b. A gas supply total pressure equal to or greater than 3 MPa.

Notes:

- 1. *9B107 includes plasma arc jet facilities and plasma wind tunnels for the study of thermal and mechanical effects of airflow on objects.*
- 2. *In 9B107 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.*

9B115 Specially designed "production equipment" for the systems, sub-systems and components specified in 9A005 to 9A009, 9A011, 9A101, 9A102, 9A105 to 9A109, 9A111, 9A116 to 9A120.

9B116 Specially designed "production facilities" for the space launch vehicles specified in 9A004, or systems, sub-systems, and components specified in 9A005 to 9A009, 9A011, 9A101, 9A102, 9A104 to 9A109, 9A111, 9A116 to 9A120 or 'missiles'.

Technical Note:

In 9B116 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.

9B117 Test benches or test stands for solid or liquid propellant rockets or rocket motors, having either of the following characteristics:

- a. The capacity to handle more than 68 kN of thrust; or
- b. Capable of simultaneously measuring the three axial thrust components.

9C Materials

- 9C108 Insulation material in bulk form and "interior lining", other than those specified in 9A008, for rocket motor cases usable in "missiles" or specially designed for solid propellant rocket engines specified in 9A007 or 9A107.

Note:

In 9C108, insulation intended to be applied to the components of a rocket motor, i.e. the case, nozzle inlets, case closures, includes cured or semi-cured compounded rubber sheet stock containing an insulating or refractory material. It may also be incorporated as stress relief boots or flaps specified in 9A108.

- 9C110 Resin impregnated fibre prepregs and metal coated fibre preforms therefor, for composite structures, laminates and manufactures specified in 9A110, made either with organic matrix or metal matrix utilising fibrous or filamentary reinforcements having a "specific tensile strength" greater than $7,62 \times 10^4$ m and a "specific modulus" greater than $3,18 \times 10^6$ m.

N.B. SEE ALSO 1C010 AND 1C210.

Note: *The only resin impregnated fibre prepregs specified in entry 9C110 are those using resins with a glass transition temperature (T_g), after cure, exceeding 418 K (145°C) as determined by ASTM D4065 or equivalent.*

9D Software

- 9D001 "Software", not specified in 9D003 or 9D004, specially designed or modified for the "development" of equipment or "technology", specified in 9A001 to 9A119, 9B or 9E003.
- 9D002 "Software", not specified in 9D003 or 9D004, specially designed or modified for the "production" of equipment specified in 9A001 to 9A119 or 9B.
- 9D003 "Software" incorporating "technology" specified in 9E003.h. and used in "Full Authority Digital Engine Control (FADEC) Systems" for systems specified in 9A or equipment specified in 9B.
- 9D004 Other "software" as follows:
- a. 2D or 3D viscous "software", validated with wind tunnel or flight test data required for detailed engine flow modelling;
 - b. "Software" for testing aero gas turbine engines, assemblies or components, having all of the following:
 1. Specially designed for testing any of the following:
 - a. Aero gas turbine engines, assemblies or components, incorporating "technology" specified in 9E003.a., 9E003.h. or 9E003.i.; or
 - b. Multi-stage compressors providing either bypass or core flow, specially designed for aero gas turbine engines incorporating "technology" specified in 9E003.a. or 9E003.h.; and
 2. Specially designed for all of the following:
 - a. Acquisition and processing of data, in real time; and
 - b. Feedback control of the test article or test conditions (e.g. temperature, pressure, flow rate) while the test is in progress;

Note: 9D004.b. does not control software for operation of the test facility or operator safety (e.g. overspeed shutdown, fire detection and suppression), or "production", repair or maintenance acceptance-testing limited to determining if the item has been properly assembled or repaired.

9D004 continued

- c. "Software" specially designed to control directional solidification or single crystal material growth in equipment specified in 9B001.a. or 9B001.c.;
- d. Not used;
- e. "Software" specially designed or modified for the operation of items specified in 9A012;
- f. "Software" specially designed to design the internal cooling passages of aero gas turbine blades, vans and "tip shrouds";
- g. "Software" having all of the following:
 - 1. Specially designed to predict aero thermal, aeromechanical and combustion conditions in aero gas turbine engines; and
 - 2. Theoretical modelling predictions of the aero thermal, aeromechanical and combustion conditions, which have been validated with actual aero gas turbine engine (experimental or production) performance data.

9D005 "Software" specially designed or modified for the operation of items specified in 9A004.e. or 9A004.f.

N.B. For "software" for items specified in 9A004.d. that are incorporated into "spacecraft mission equipment", see the appropriate Categories.

9D101 "Software" specially designed or modified for the "use" of goods specified in 9B105, 9B106, 9B107, 9B116 or 9B117.

9D103 "Software" specially designed for modelling, simulation or design integration of the space launch vehicles specified in 9A004, sounding rockets specified in 9A104 or "missiles", or the subsystems specified in 9A005, 9A007, 9A105, 9A106.c., 9A107, 9A108.c., 9A116 or 9A119.

Note: "Software" specified in 9D103 remains controlled when combined with specially designed hardware specified in 4A102.

9D104 "Software" as follows:

- a. "Software" specially designed or modified for the "use" of goods specified in 9A001, 9A005, 9A006.d., 9A006.g., 9A007.a., 9A009.a., 9A010.d., 9A011, 9A101, 9A102, 9A105, 9A106.d., 9A107, 9A109, 9A111, 9A115.a., 9A117 or 9A118.
- b. "Software" specially designed or modified for the operation or maintenance of subsystems or equipment specified in 9A008.d., 9A106.c., 9A108.c. or 9A116.d.

9D105 "Software" specially designed or modified to coordinate the function of more than one subsystem, other than that specified in 9D004.e., in space launch vehicles specified in 9A004 or sounding rockets specified in 9A104 or 'missiles'

Note: 9D105 includes "software" specially designed for a manned "aircraft" converted to operate as "unmanned aerial vehicle", as follows:

- a. "Software" specially designed or modified to integrate the conversion equipment with the "aircraft" system functions; and
- b. "Software" specially designed or modified to operate the "aircraft" as an "unmanned aerial vehicle".

Technical Note:

In 9D105 'missile' means complete rocket systems and unmanned aerial vehicle systems capable of a range exceeding 300 km.

9E Technology

Note: "Development" or "production" "technology" specified in 9E001 to 9E003 for gas turbine engines remains controlled when used for repair or overhaul. Excluded from control are: technical data, drawings or documentation for maintenance activities directly associated with calibration, removal or replacement of damaged or unserviceable line replaceable units, including replacement of whole engines or engine modules.

9E001 "Technology" according to the General Technology Note for the "development" of equipment or "software", specified in 9A004 to 9A012, 9A350, 9B or 9D.

9E002 "Technology" according to the General Technology Note for the "production" of equipment specified in 9A004 to 9A011, 9A350 or 9B.

N.B. For "technology" for the repair of controlled structures, laminates or materials, see 1E002.f.

9E003 Other "technology" as follows:

Note: 9E003 includes technology applicable to aero, aero-derivative, marine or industrial gas turbine engines.

a. "Technology" "required" for the "development" or "production" of any of the following gas turbine engine components or systems:

1. Turbine blades, vanes or "tip shrouds", made from directionally-solidified or single-crystal alloys and having (in the 001 Miller Index Direction) a stress-rupture life exceeding 400 hours at 1 273 K (1 000°C) at a stress of 200 MPa, based on the average property values;

Technical Note:

For the purposes of 9E003.a.1., stress-rupture life testing is typically conducted on a test specimen.

2. Combustors having any of the following:

- a. 'Thermally decoupled liners' designed to operate at 'combustor exit temperature' exceeding 1 883K (1 610°C);
- b. Non-metallic liners;
- c. Non-metallic shells;
- d. Liners designed to operate at 'combustor exit temperature' exceeding 1 883 K (1 610°C) and having holes that meet the parameters specified in 9E003.c.; or
- e. 'Pressure gain combustion';

Note: The "required" "technology" for holes in 9E003.a.2. is limited to the derivation of the geometry and location of the holes.

Technical Notes:

1. *For the purposes of 9E003.a.2.a., 'thermally decoupled liners' are liners that feature at least a support structure designed to carry mechanical loads and a combustion facing structure designed to protect the support structure from the heat of combustion. The combustion facing structure and support structure have independent thermal displacement (mechanical displacement due to thermal load) with respect to one another, i.e., they are thermally decoupled.*
2. *For the purposes of 9E003.a.2.a. and 9E003.a.2.d., 'combustor exit temperature' is the bulk average gas path total (stagnation) temperature between the combustor exit plane and the leading edge of the turbine inlet guide vane (i.e., measured at engine station T40 as defined in SAE ARP 755A) when the engine is running in a "steady state mode" of operation at the certificated maximum continuous operating temperature.*
3. *For the purposes of 9.E.3.a.2.e., 'pressure gain combustion' refers to a combustor where the bulk average stagnation pressure at the combustor outlet is greater than the bulk average stagnation pressure at the combustor inlet due primarily to the combustion process, when the engine is running in a "steady state mode" of operation.*

N.B. *For "technology" "required" for manufacturing cooling holes, see 9E003.c.*

3. Components that are any of the following:
 - a. Manufactured from organic "composite" materials designed to operate above 588 K (315°C);
 - b. Manufactured from any of the following:
 1. Metal "matrix" "composites" reinforced by any of the following:
 - a. Materials specified in 1C007 or 1C507;
 - b. "Fibrous or filamentary materials" specified in 1C010;
or
 - c. Aluminides specified in 1C002.a.; or
 2. Ceramic "matrix" "composites" specified in 1C007 or 1C507;
or

9E003.a.3. continued

- c. Stators, vanes, blades, tip seals (shrouds), rotating blings, rotating blisks, or 'splitter ducts', that are all of the following:
 - 1. Not specified in 9E003.a.3.a.;
 - 2. Designed for compressors or fans; and
 - 3. Manufactured from material specified in 1C010.e. with resins specified in 1C008;

Technical Note:

For the purposes of 9E003.a.3.c., a 'splitter duct' performs the initial separation of the air-mass flow between the bypass and core sections of the engine.

- 4. Uncooled turbine blades, vanes or "tip shrouds", designed to operate at a 'gas path temperature' of 1 373 K (1 100°C) or more;

9E003.a. continued

5. Cooled turbine blades, vanes, "tip shrouds" other than those described in 9E003.a.1., designed to operate at a 'gas path temperature' of 1 693 K (1 420°C) or more;

Technical Note:

For the purposes of 9E003.a.4. and 9E003.a.5., 'gas path temperature' is the bulk average gas path total (stagnation) temperature at the leading edge plane of the turbine component when the engine is running in a "steady state mode" of operation at the certificated or specified maximum continuous operating temperature.

6. Aerofoil-to-disk blade combinations using solid-state joining;
7. Not used;
8. 'Damage tolerant' rotor components using powder metallurgy materials specified in 1C002.b.; or

Technical Note:

For the purposes of 9E003.a.8., 'damage tolerant' components are designed using methodology and substantiation to predict and limit crack growth.

9. Not used;
10. Not used;
11. 'Fan blades' having all of the following:
 - a. 20% or more of the total volume being one or more closed cavities containing vacuum or gas only; and
 - b. One or more closed cavities having a volume of 5 cm³ or larger;

Technical Note:

For the purposes of 9E003.a.11., a 'fan blade' is the aerofoil portion of the rotating stage or stages, which provide both compressor and bypass flow in a gas turbine engine.

9E003 continued

- b. "Technology" "required" for the "development" or "production" of any of the following:
 - 1. Wind tunnel aero-models equipped with non-intrusive sensors capable of transmitting data from the sensors to the data acquisition system; or
 - 2. "Composite" propeller blades or propfans, capable of absorbing more than 2 000 kW at flight speeds exceeding Mach 0,55;
- c. "Technology" "required" for manufacturing cooling holes in gas turbine engine components incorporating any of the "technologies" specified in 9E003.a.1., 9E003.a.2. or 9E003.a.5., and having any of the following:
 - 1. Having all of the following:
 - a. Minimum 'cross-sectional area' less than 0,45 mm²;
 - b. 'Hole shape ratio' greater than 4,52; and
 - c. 'Incidence angle' equal to or less than 25°; or
 - 2. Having all of the following:
 - a. Minimum 'cross-sectional area' less than 0,12 mm²;
 - b. 'Hole shape ratio' greater than 5,65; and
 - c. 'Incidence angle' more than 25°;

Note: 9E003.c. does not control "technology" for manufacturing constant radius cylindrical holes that are straight through and enter and exit on the external surfaces of the component.

Technical Notes:

For the purposes of 9E003.c.:

- 1. *The 'cross-sectional area' is the area of the hole in the plane perpendicular to the hole axis.*
- 2. *'Hole shape ratio' is the nominal length of the axis of the hole divided by the square root of its minimum 'cross-sectional area'.*
- 3. *'Incidence angle' is the acute angle measured between the plane tangential to the aerofoil surface and the hole axis at the point where the hole axis enters the aerofoil surface.*
- 4. *Methods for manufacturing holes include "laser" beam machining, water jet machining, Electro-Chemical Machining (ECM) or Electrical Discharge Machining (EDM).*

9E003 continued

- d. "Technology" "required" for the "development" or "production" of helicopter power transfer systems or tilt rotor or tilt wing "aircraft" power transfer systems;
- e. "Technology" for the "development" or "production" of reciprocating diesel engine ground vehicle propulsion systems having all of the following:
 - 1. 'Box volume' of 1,2 m³ or less;
 - 2. An overall power output of more than 750 kW based on 80/1269/EEC, ISO 2534 or national equivalents; and
 - 3. Power density of more than 700 kW/m³ of 'box volume';

Technical Note:

For the purposes of 9E003.e., 'box volume' in 9E003.e. is the product of three perpendicular dimensions measured in the following way:

Length: *The length of the crankshaft from front flange to flywheel face;*

Width: *The largest of any of the following:*

- a. *The outside dimension from valve cover to valve cover;*
- b. *The dimensions of the outside edges of the cylinder heads;*
- or
- c. *The diameter of the flywheel housing;*

Height: *The largest of any of the following:*

- a. *The dimension of the crankshaft centre-line to the top plane of the valve cover (or cylinder head) plus twice the stroke; or*
- b. *The diameter of the flywheel housing.*

- f. "Technology" "required" for the "production" of specially designed components for "high output diesel engines", as follows:
 - 1. "Technology" "required" for the "production" of engine systems having all of the following components employing ceramics materials specified in 1C007 or 1C507:
 - a. Cylinder liners;
 - b. Pistons;
 - c. Cylinder heads; and
 - d. One or more other components (including exhaust ports, turbochargers, valve guides, valve assemblies or insulated fuel injectors);

9E003.f. continued

2. "Technology" "required" for the "production" of turbocharger systems with single-stage compressors and having all of the following:
 - a. Operating at pressure ratios of 4:1 or higher;
 - b. Mass flow in the range from 30 to 130 kg per minute; and
 - c. Variable flow area capability within the compressor or turbine sections;
3. "Technology" "required" for the "production" of fuel injection systems with a specially designed multifuel (e.g., diesel or jet fuel) capability covering a viscosity range from diesel fuel (2,5 cSt at 310,8 K (37,8°C)) down to gasoline fuel (0,5 cSt at 310,8 K (37,8°C)) and having all of the following:
 - a. Injection amount in excess of 230 mm³ per injection per cylinder; and
 - b. Electronic control features specially designed for switching governor characteristics automatically depending on fuel property to provide the same torque characteristics by using the appropriate sensors;
- g. "Technology" "required" for the "development" or "production" of "high output diesel engines" for solid, gas phase or liquid film (or combinations thereof) cylinder wall lubrication and permitting operation to temperatures exceeding 723 K (450°C), measured on the cylinder wall at the top limit of travel of the top ring of the piston;

- h. "Technology" for gas turbine engine "Full Authority Digital Engine Control (FADEC) systems" as follows:
 - 1. "Development" "technology" for deriving the functional requirements for the components necessary for the "FADEC system" to regulate engine thrust or shaft power (e.g., feedback sensor time constants and accuracies, fuel valve slew rate);
 - 2. "Development" or "production" "technology" for control and diagnostic components unique to the "FADEC system" and used to regulate engine thrust or shaft power;
 - 3. "Development" "technology" for the control law algorithms, including "source code", unique to the "FADEC system" and used to regulate engine thrust or shaft power;

Note: 9E003.h. does not control technical data related to engine-"aircraft" integration required by the civil aviation authorities of one or more Member States or Wassenaar Arrangement Participating States to be published for general airline use (e.g., installation manuals, operating instructions, instructions for continued airworthiness) or interface functions (e.g., input/output processing, airframe thrust or shaft power demand).

- i. "Technology" for gas turbine engine adjustable flow path systems designed to maintain engine stability for gas generator turbines, fan or power turbines, or propelling nozzles, as follows:
 - 1. "Development" "technology" for deriving the functional requirements for the components that maintain engine stability;
 - 2. "Development" or "production" "technology" for components unique to the adjustable flow path system and that maintain engine stability;
 - 3. "Development" "technology" for the control law algorithms, including "source code", unique to the adjustable flow path system and that maintain engine stability;

Note: 9E003.i. does not control "technology" for any of the following:

- a. Inlet guide vanes;
- b. Variable pitch fans or prop-fans;
- c. Variable compressor vanes;
- d. Compressor bleed valves; or
- e. Adjustable flow path geometry for reverse thrust.

- j. "Technology" "required" for the "development" of wing-folding systems designed for fixed-wing "aircraft" powered by gas turbine engines;

N.B. For "technology" "required" for the "development" of wing-folding systems designed for fixed-wing "aircraft" SEE ALSO MILITARY GOODS CONTROLS.

- k. "Technology", not specified in 9E003.a., 9E003.h., or 9E003.i., "required" for the "development" of any of the following components or systems, specially designed for aero gas turbine engines to enable "aircraft" to cruise at Mach 1 or greater for more than 30 minutes:

1. Propulsion inlet systems;
2. Propulsion exhaust systems;
3. 'Reheat systems';
4. 'Active thermal management systems' to condition fluids used to lubricate or cool 'engine rotor supports';
5. Oil-free 'engine rotor supports'; or
6. Systems to remove heat from 'compression system' core gas path flow.

Technical Notes:

For the purposes of 9E003.k.:

1. Propulsion inlet systems include core flow pre-coolers.
2. 'Reheat systems' provide additional thrust by combusting fuel in exhaust and/or bypass flow downstream of the last turbomachinery stage. 'Reheat systems' are also referred to as afterburners.
3. 'Active thermal management systems' employ methods other than passive oil-to-air cooling or oil-to-fuel cooling, such as vapour cycle systems.
4. 'Compression system' is any stage or combination of stages between the engine inlet face and the combustor that increases gas path pressure through mechanical work.
5. An 'engine rotor support' is the bearing supporting the main engine shaft that drives the compression system or turbine rotors.

N.B.1 For engine control technology, see 9E003.h.

N.B.2 For adjustable flow path systems technology, see 9E003i.

9E101 "Technology" as follows:

- a. "Technology" according to the General Technology Note for the "development" of goods specified in 9A101, 9A102, 9A104 to 9A111, 9A112.a. or 9A115 to 9A121.
- b. "Technology" according to the General Technology Note for the "production" of 'UAV's specified in 9A012 or goods specified in 9A101, 9A102, 9A104 to 9A111, 9A112.a. or 9A115 to 9A121.

Technical Note:

In 9E101.b. 'UAV' means unmanned aerial vehicle systems capable of a range exceeding 300 km.

9E102 "Technology" according to the General Technology Note for the "use" of space launch vehicles specified in 9A004, goods specified in 9A005 to 9A011, 'UAV's specified in 9A012 or goods specified in 9A101, 9A102, 9A104 to 9A111, 9A112.a., 9A115 to 9A121, 9B105, 9B106, 9B107, 9B115, 9B116, 9B117, 9D101 or 9D103.

Technical Note:

In 9E102 'UAV' means unmanned aerial vehicle systems capable of a range exceeding 300 km.'

9E503 Other "technology" as follows:

Note: *9E503 includes technology applicable to aero, aero-derivative, marine or industrial gas turbine engines.*

1. "Technology" "required" for the "development" of a gas turbine engine axial compressor having all of the following:
 1. Having any of the following:
 - a. Specially designed for 'multiple stream fan systems'; or
 - b. Having any of the following:
 1. Feedback control of compressor blade tip clearance;
 2. Feedback management for the purpose of compressor aerofoil flutter avoidance;
 3. Cooled gas path or cooled rotating compressor components;
 4. 'Tandem or splitter rotating aerofoils'; or
 5. 'Casings having non-axisymmetric geometry' at the blade tip interface; and
 2. Having all of the following calculated parameters:
 - a. Average 'alternate stage loading' greater than or equal to 0,22;
 - b. A sum of the 'alternate stage loading' multiplied by 41,6 and the 'polytropic efficiency' greater than or equal to 102;

- c. 'Stability margin' greater than or equal to 20%; and
- d. Average stage pressure ratio greater than 1,2.

Technical Notes:

1. *For the purposes of 9E503.1.1.a., 'multiple stream fan systems' allow the movement of airflow between at least two bypass flows to control fan pressure ratio or bypass ratio (by means other than use of fan corrected speed or the primary nozzle area to change the fan pressure ratio or bypass ratio.)*
2. *For the purposes of 9E503.1.1.b.3., cooled gas path components do not include compressor components indirectly cooled by leakage flows, flows for bearing load management or anti-icing flows.*
3. *For the purposes of 9E503.1.1.b.4., 'tandem or splintered rotating aerofoils' consist of two or more rotating blade rows in the axial direction without an intervening stator. Aerofoils are considered splintered when the leading-edge plane of each row is offset axially by 25% or more of the axial chord length of the first row.*
4. *For the purposes of 9E503.1.1.b.5., 'casings having non-axisymmetric geometry' contain features that are non-uniformly spaced or inconsistently shaped or inconsistently oriented in the circumferential direction at the blade tip, e.g., variable spacing of slots parallel to the engine shaft. 'Casings having non-axisymmetric geometry' do not include features designed for assembly or mechanical designs that result in circumferentially uniform geometry during engine operation.*
5. *For the purposes of 9E503.1.2, the calculated parameters are as follows:*
 - a. *Start at the engine inlet and are performed at sea level static conditions using ICAO standard atmosphere, zero aircraft bleed (e.g., no stability, start, anti-ice or customer bleeds), and at the "steady state mode" 'Aerodynamic Design Point' ('ADP'). Compressor bleeds and "steady state mode" shaft power offtake for normal engine operation at the specified point, e.g., turbine cooling, are included.*
 - b. *Stages that provide fan bypass flow on a continuous basis are not to be included in the calculations.*
 - c. *Values are calculated for each rotor stage individually, then averaged over all compression stages operating at the same shaft speed (i.e., average of all low-, intermediate-, or high-pressure compressor stages, or all compression stages for a single spool engine)*
 - d. *'Alternate stage loading' is defined as the average isentropic work divided by the square of the mechanical tip speed of the rotor and then multiplied by the ratio of standard day temperature divided by the spool inlet total temperature.*

$$Lp'_{alt} = \frac{T_{STD}}{T_{0spool}} \frac{1}{N} \sum_{i=1}^N \frac{c_{p_i} T_{0i} (\pi_i^{(\gamma_i-1)/\gamma_i} - 1)}{U_i^2}$$

Where:

T_{STD} - Standard day temperature at ICAO standard atmosphere (K)

T_{0spool} - Spool entrance inlet temperature (K)

N - Number of stages

T_0 - Stage inlet total temperature (K)

c_p - Specific heat capacity ($J\ kg^{-1}\ K^{-1}$ or $m^2\ s^{-2}\ K^{-1}$) as a function of temperature

γ - Ratio of specific heats as a function of temperature

U - Mechanical tip speed of the rotor leading edge (m/s)

π - Stage total-to-total pressure ratio

The individual stage loading should be computed stage-by-stage and then the average of all stages should be assessed as the loading parameter.

- e. 'Polytropic efficiency' is defined as the overall compression divided into an infinite number of small steps with the same isentropic efficiency, expressed as a percentage.
 - f. 'Stability margin' is the difference between the design operating line and the calculated compressor surge point at constant inlet corrected mass flow, expressed as a percent of the operating line.
6. For the purposes of Technical Note 5.a., 'ADP' refers to the corrected conditions (flow rate, pressure ratio, and speed) for the compressor flow path design (e.g. optimum efficiency or optimum incidence point). The 'ADP' may be consistent with an aero gas turbine engine 'ADP' or a specific condition along an operating line such as top of climb, cruise, or takeoff.'