# Annex V*

# List of Items, Materials, Equipment, Goods and Technology Related to Ballistic Missile Programs

Pursuant to resolution 2087 (2013) for the DPRK sanctions regime; and pursuant to resolution 1929 (2010) for the Iran sanctions regime
(corresponding with document S/2012/947)

* Annex V to Enrico Carisch and Loraine Rickard-Martin, "United Nations Sanctions of Iran and North Korea: An Implementation Manual," New York: International Peace Institute, March 2014.

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# ITEM 1: COMPLETE DELIVERY SYSTEMS

1.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**1.A.1. Complete rocket systems, including ballistic missile systems, space launch vehicles, and sounding rockets, that are capable of delivering at least a 500 kg "payload" to a "range" of at least 300 km.**

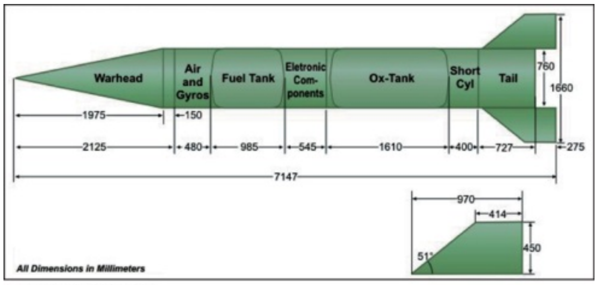



Figure 1. Al Samud II diagram.

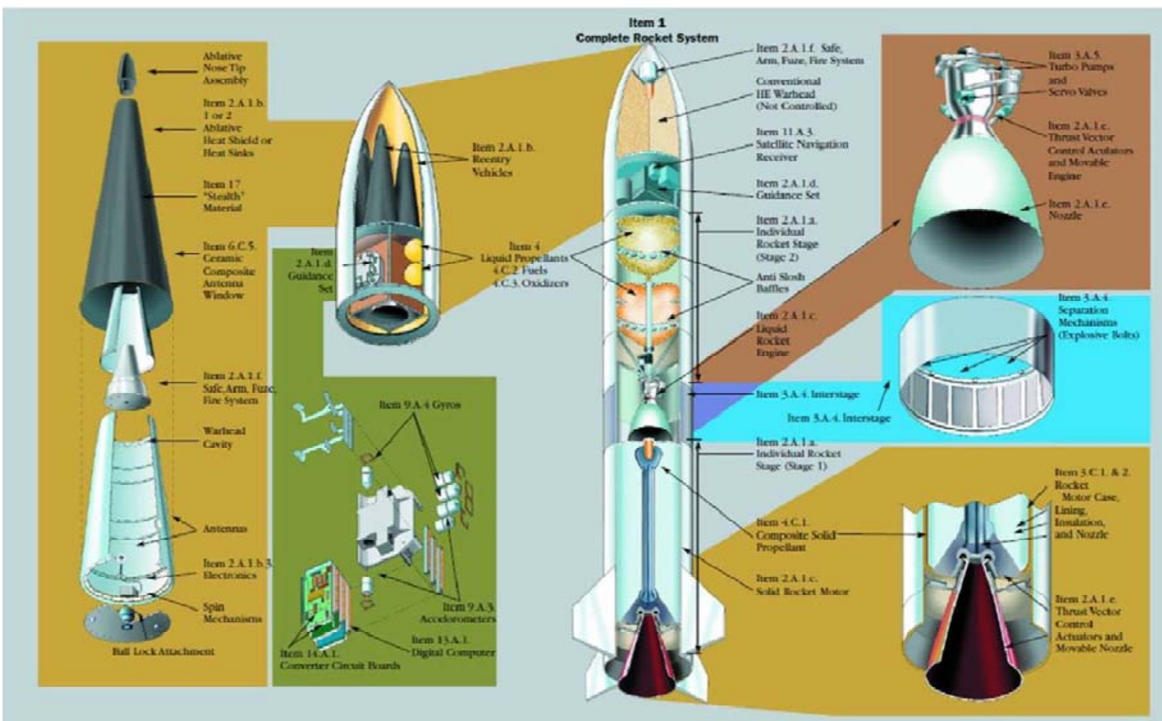




Figure 4: Expanded view of a notional ballistic missile showing MTCR Annex items. (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005))

Global Production: Brazil, China, Canada, Egypt, France, Germany, India, Israel, Iran, Italy, Japan, North Korea, Pakistan, Russian Federation, Republic of Korea, Spain, Syria, Ukraine, United Kingdom, United States

Sellers: Democratic People's Republic of Korea

Manufacturers: Russian Federation; Possible new suppliers: Egypt, India, Iran, Israel, Pakistan, Syria, Brazil, South Africa

Complete rocket systems are large, long, narrow cylinders. When assembled, these systems typically have dimensions of at least 8 m in length, 0.8 m in diameter, and 5,000 kg in weight, with a full load of propellant.

The forward end, or nose, typically has a conical, elliptical, or bulbous fairing that houses the payload, and joins to the cylindrical body in which the propellants are located. The blunt aft end is straight, flared, or symmetrically finned for stability during launch and atmospheric flight. The body of the rocket system houses the rocket motor(s), which supplies the thrust. The rocket system surface is usually made of metallic or composite materials with heat absorbing materials or protective coatings. Depending on their intended use, some surfaces may be unfinished.

Solid engine rocket: "Solid propellant missiles can be stored and transported while already fueled and can be launched very quickly, leaving them less vulnerable during launch preparations. Therefore, the successful development of solid-fueled rockets is a significant achievement in ballistic missile design. The International Institute for Strategic Studies has called Iran's shift to solid-fueled ballistic missiles 'a turning point' with 'profound strategic implications' because this technological advancement will greatly aid Iran in the development and deployment of true long-range missiles." Matthew Fargo, "Ballistic Missile Technology 101—Rocket Fuel," Center for Strategic and International Studies, August 8, 2012, available at http://csis.org/blog/ballistic-missile-technology-101-rocket-fuel .

A complete rocket system is seldom packaged as a fully assembled unit for shipment from the manufacturer to its point of use or storage. Instead, the major subsystems are shipped in crates or sealed metal containers to an assembly facility near the launch location. Exceptions include mobile ballistic missiles, which can be fully assembled and stored in a horizontal position in a mobile transporter erector launcher (TEL) and moved to the launch point when required.

**1.A.2. Complete unmanned aerial vehicle systems (including cruise missile systems, target drones and reconnaissance drones) capable of delivering at least a 500 kg "payload" to a "range" of at least 300 km.**

Figure 5: A High Altitude Long Endurance (HALE) Unmanned Aerial Vehicle (UAV). (U.S. Air Force)

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Figure 7: An operational cruise missile on its checkout stand, showing its nose cone modified to lower radar returns and enhance aerodynamic performance. (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005))

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Figure 6: A UAV armed with air-to-surface missiles. (General Atomics Aeronautical Systems, Inc.)

Sourced: Missile Technology Control Regime Annex Handbook - 2010

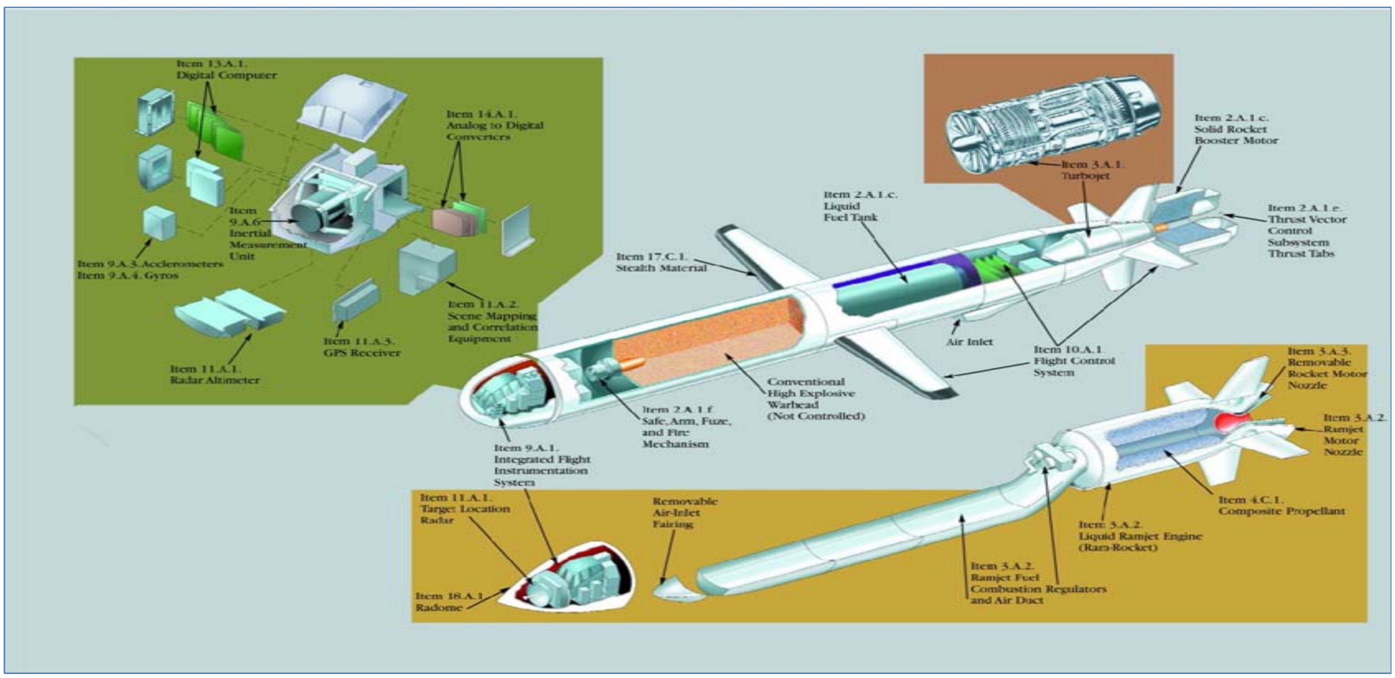



Figure 8: Expanded view of a notional cruise missile showing MTCR Annex items. (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005))

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Complete unmanned aerial vehicle systems (including cruise missile systems, target drones and reconnaissance drones) capable of delivering at least a 500 kg "payload" to a "range" of at least 300 km.

Global Production: Australia, China, France, Germany, Israel, Pakistan, Russian Federation, United States

Large UAVs will vary in appearance because of their role-specific designs, but most will have common features, including large (and often slender) wing-spans of between 20 m and 40 m, and distinctive domes toward the front end of the fuselage housing avionics and electrical components, including satellite communication (SATCOM) antenna, line of sight transceiver antenna, navigation instruments and global positioning systems (GPS). Weaponized UAVs will typically have external wing stations for payload carriage.

Cruise missiles usually have a cylindrical or box-like cross-section and a fineness ratio (ratio of length to diameter) between 8 to 1 and 10 to 1. Most have a lifting surface, or wings, and most use control fins at the tail (some have ailerons on the wings and/or canards).

UAVs, including cruise missiles, are manufactured in components or sections at different locations and by different manufactures. These sections may vary in size from less than 10 kg and 0.03 $m^3$ to 150 kg and 0.1 $m^3$ to 1 $m^3$ or larger, depending on the class of UAV. Large UAVs can be disassembled, loaded and shipped in heavy cardboard containers; medium-size sections require heavy wooden crates. The wings of large UAVs are detached from the fuselage, and each section is crated separately for shipping by truck, rail, or cargo aircraft. Most cruise missiles are shipped fully assembled in environmentally sealed metal canisters, which can also serve as launching tubes. Their wings are often folded either within or along the missile body, and the tail fins are often folded on longitudinal hinges in order to fit within the launch canister or on the launch platform and open after launch to control the missile.

# ITEM 1: COMPLETE DELIVERY SYSTEMS

1.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

Democratic People's Republic of Korea launch sites:

Tongchang-ri (Sohae), Musudan-ri (Tonghae) (UN Doc. S/2012/422)
Islamic Republic of Iran launch sites: Khomeini Space Centre, Semnan Space Centre (UN Doc. S/2013/331)

Reports of rocket site construction: Associated Press, "North Korea: Construction Seen at Rocket Site, Institute Reports," *The New York Times*, November 29, 2013, available at www.nytimes.com/2013/11/30/world/asia/north-korea-construction-seen-at-rocket-site-institute-reports.html?ref=asia .

Map of production facililities: See Nuclear Threat Initiative map at www.nti.org/gmap/?place=29.6785,83.1994,3&layers=missile_base,missile_production,missile_acquisition,missile_research_and_development,missile_design .

Above: Aerial view of Semnan Missile Base in Iran, DigitalGlobe 2011 image.

## ITEM 1: COMPLETE DELIVERY SYSTEMS

1.C. MATERIALS S/2012/947 Category 1

No further information.

## ITEM 1: COMPLETE DELIVERY SYSTEMS

1.D. SOFTWARE S/2012/947 Category 1

**1.D.1. "Software" Specially Designed or Modified for the "Use" of "Production Facilities" Specified In 1.B.**

Typically this software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs and documents can contain this software and data.

**1.D.2. "Software" Which Coordinates the Function of More Than One Subsystem, Specially Designed or Modified for "Use" in Systems Specified in 1.A.**

Typically this software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs and documents can contain this software and data.

## ITEM 1: COMPLETE DELIVERY SYSTEMS

1.E. TECHNOLOGY S/2012/947 Category 1

**1.E.1. "Technology," in Accordance with the General Technology Note, for The "Development," "Production" or "Use" of Equipment or "Software" Specified In 1.A., 1.B., or 1.D.**

## ITEM 2: COMPLETE SUBSYSTEMS USABLE FOR COMPLETE DELIVERY SYSTEMS

2.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**2.A.1.A. Individual Rocket Stages Usable in the Systems Specified in 1.A.**

Safir Space Launch Vehicle First Stage: UN Doc. S/2012/395

Safir Second Stage: UN Doc. S/2012/395

Top: Shipping Container for a liquid fueled upper stage

Sourced: Missile Technology Control Regime Annex Handbook - 2010

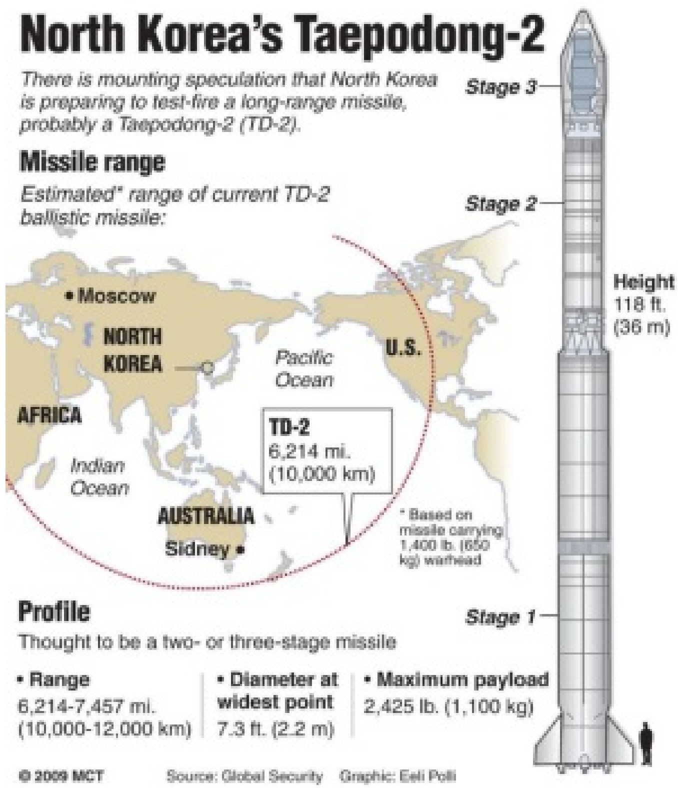



Photo above: North Korea's most recent developed missile. Photo shows stages and gives a profile of the missile.

Propulsion stage: Liquid, solid, hybrid propellant used to propel the missile out of the atmosphere.

The Safir reportedly has a length of 22 m, a core diameter of 1.25 m and a launch weight of 26,000 kg. The first stage of the Safir is derived from the Ghadr-1 missile, a variant of the Shahab-3 medium-range ballistic missile. It is believed to be 13.5 m long, with a mass of 18,000 kg. The Safir's second stage is estimated to be 8.5 m in length with a mass of 8,000 kg. (UN Doc. S/2012/395)

Solid propellant rocket motor stages are cylinders usually ranging from 4 m to 10 m in length and 0.5 m to 4 m in diameter, and capped at each end with hemispherical domes. The cylinders generally are made of high-strength sheet steel, a composite of filament-wound fiber in a resin matrix, or a combination of both, and may be covered by an insulating material such as cork or rubber sheet. Because these stages are nearly completely filled with high-density, rubber-like propellant, they may weigh as much as 1,600 kg per m3 of stage volume.

Liquid propellant rocket engine stages are cylindrical and capped at one end with a hemispherical dome. A conical-shaped nozzle or nozzles are attached to the rear of the stage at the outlet of the combustion chamber. Liquid propellant rocket engine stages are usually made of thin metallic sheets, with internal rings to provide stiffness. Because these stages are empty when shipped, they may weigh as little as 240 kg to 320 kg per m3 of stage volume.

The Safir reportedly has a length of 22 m, a core diameter of 1.25 m and a launch weight of 26,000 kg. The first stage of the Safir is derived from the Ghadr-1 missile, a variant of the Shahab-3 medium-range ballistic missile. It is believed to be 13.5 m long, with a mass of 18,000 kg. The Safir's second stage is estimated to be 8.5 m in length with a mass of 8,000 kg. (UN Doc. S/2012/395)

Virtually all rocket stages are shipped in containers or fixtures specifically designed for them. Smaller solid propellant rocket stages can be shipped in wooden crates with internal restraints and shock mounts. Larger solid propellant stages are more often shipped in specially designed metallic containers, usually cylindrical in appearance and sometimes filled with an inert atmosphere. Very large stages may be simply wrapped with a protective covering

**2.A.1.b . Re-entry vehicles, and equipment designed or modified therefor, usable in the systems specified in 1.A.**

1. **Heat shields, and components therefor, fabricated of ceramic or ablative materials;**
2. **Heat sinks and components therefor, fabricated of light-weight, high heat capacity materials;**
3. **Electronic equipment specially designed for re-entry vehicles;**

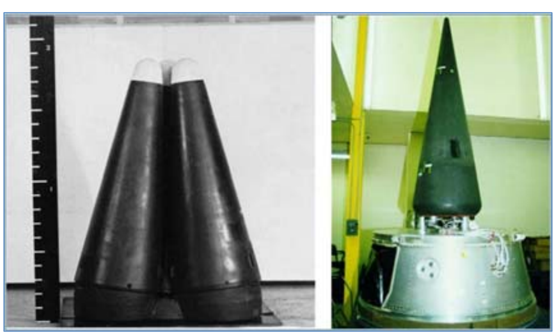


Figure 3: *Left:* Three modern RVs attached to their mounting flange. The small fins at the aft end spin-stabilize the RVs as they re-enter the atmosphere. *Right:* A modern RV on its payload support bulkhead. (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005))

Sourced: Missile Technology Control Regime Annex Handbook - 2010

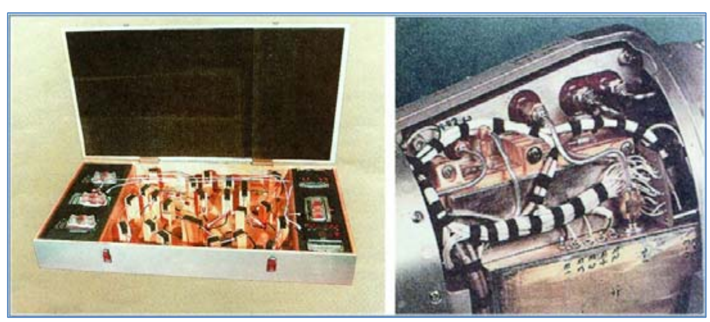


Figure 6: Left: An RV radar antenna set packaged for shipment. Right: A portion of RV radar electronics. (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005))

Sourced: Missile Technology Control Regime Annex Handbook - 2010

RVs are conical-shaped structures (some with several cone angles), usually with a hemispherically rounded nose tip. The base, or rear, of the vehicle may be hemispherical or blunt. Small fins for aerodynamic stability may be attached at several locations at the rear of the conical surface. The conic surface is covered with a heat shield, which may be naturally colored (black for carbon-based heat shields, tan or yellow for silica-based shields) or may be painted. Advanced technology RVs are usually long, thin cones with sharp nosetips (see Figure 4). They may have small ceramic inserts that serve as antenna windows at several locations on the conical surface.

Heat shields and heat sinks usually have the same size and shape as their underlying RVs. In some cases, they cover only the forward portion of the RV nose cone. Sizes for missile applications range from 1 m to 3 m in length and less than 1 m in diameter. Shields are generally conical or ogival, with pointed or rounded noses. They are either bonded to the RV or slipped over it in order to achieve a close fit.

The usual components of an RV electronics package are unremarkable in appearance. The largest and most distinctive part is probably the battery, which may be roughly half the size of an automobile battery but is often considerably smaller. Most of the remaining electronic components are small and are usually housed in aluminum boxes. The SAFF system is assembled by the RV manufacturer and is unlikely to be obtained as a prepackaged unit. Such equipment may have a disk, conical, or truncated-cone appearance because it is designed to fit tightly into an RV. Any indication of special capabilities to withstand high acceleration or severe vibration may suggest a missile application

RVs intended for multiple-warhead missiles are usually less than 3 m long and less than 1 m in base diameter. RVs used on missiles carrying a single weapon often have diameters equal to that of the uppermost stage, and typically have lengths between 1 m and 4 m. RVs, including the weapons they contain, typically range in weight from slightly less than 100 kg to roughly 1,000 kg.

The RV sections are usually transported together in special containers, either wood or steel, not much larger than the RV itself. They are shock-isolated and supported at several locations inside the shipping container, which may be environmentally controlled.

Missile RV heat shields, heat sinks, and their components are small enough to be packaged in conventional shipping boxes or crates for protection from damage.

### 2.A.1.C. Solid Propellant Rocket Motors, Hybrid Rocket Motors or Liquid Propellant Rocket Engines, Usable in the Systems Specified in 1.A., Having a Total Impulse Capacity Equal to or Greater Than 1.1 X 106 Ns

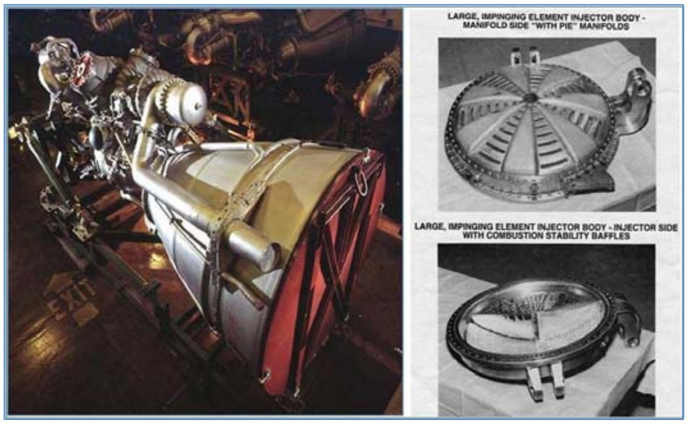



Figure 8: *Left:* A second-stage oxygen/kerosene liquid propellant rocket engine. (Aerojet) *Right:* The dome of an injector head (top picture) and its underside, showing the injectors and baffles (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005))

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Figure 7: *Top left:* A re-usable solid rocket motor for space vehicle use. (ATK) *Bottom left:* Solid propellant rocket motors with total impulse close to the lower limit of Item 2 control. (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005)) *Right:* A pressure-fed liquid rocket engine. (Aerojet)

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Solid rocket motors are cylindrical tubes with spherical or elliptical domes at both ends. One dome could have a small hole for attaching the igniter; the other dome could have a larger hole for attaching the nozzle. Approximately 450 kg of propellant is required to achieve the 2.A.1.c. threshold impulse of equal to or greater than 1.1 x 106 Ns. Rocket motors containing this quantity of propellant would be approximately 4 m in length and 0.5 m in diameter. A rocket motor of this size would usually have a steel case, although composite cases made of glass, carbon, or para-aramid fiber are possible.

Liquid rocket engines are characterized by a cylindrical or spherical combustion chamber to which a converging/diverging nozzle is attached. The nozzle is usually larger than the rest of the engine. A number of pipes, tubes, and pumps are attached to the top and sides of the combustion chamber.

Solid rocket motors are usually shipped in steel or aluminum containers or wooden crates. Crates have cradles at several points to support the weight of the motor and are usually lined with foam or cushioning material to protect the motor during shipment. Rocket motors are sometimes packaged in an inert atmosphere to keep the propellant protected from moisture. These containers are typically hermetically sealed, pressurized, and made of aluminum.

Liquid rocket engines are rugged devices, but they must be protected from shock and moisture. Typical containers include large wooden crates and metal containers.

### 2.A.1.D. "Guidance Sets," Usable in the Systems Specified in 1.A., 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)

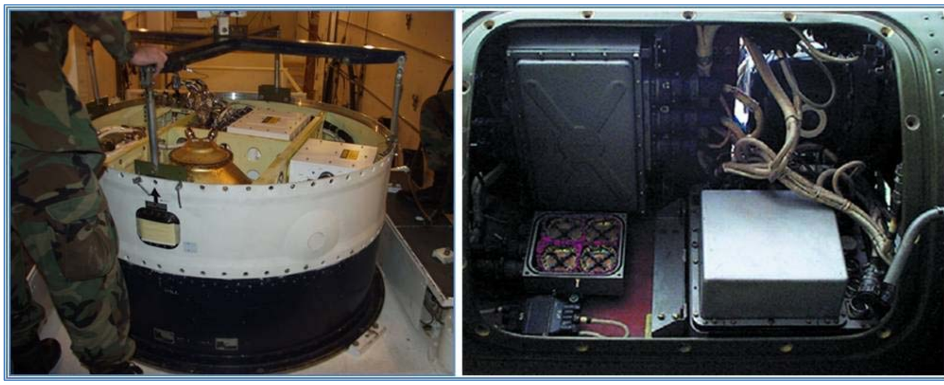


Figure 9: *Left:* A missile guidance set being transported to a launch facility. (Northrop Grumman) *Right:* An older-technology guidance set, composed several components, installed in a missile. (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005))

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Guidance systems direct the payload to a certain trajectory. Reliable systems are necessary and important, especially in the case of Multiple Independently Targetable Reentry Vehicles (MIRV).

A "guidance set" integrates the process of measuring and computing a vehicle's position and velocity (i.e., navigation) with that of computing and sending commands to the vehicle's flight control systems to correct the trajectory.

The size, weight, and appearance of guidance sets vary with the type of missile because of the structural features of the missile and variations in mission requirements. Older designs tend to be larger and heavier (up to around 1 m on a side / diameter and up weighing up to 100 kg); new systems, which are significantly more accurate, may require only 30 cm on a side and weigh a few kilograms. Most sets are enclosed in metallic boxes that have airtight but removable access panels. They are often rectangular, but they can also be cylindrical or be comprised of several boxes of various shapes. Guidance sets also have quality electrical connectors, precision-mounting surfaces, and, in some cases, temperature control connections.

Because most guidance sets are very expensive and sensitive to damage from shock, they are shipped in cushioned containers, some of them special and air-tight, to protect them from moisture. These containers usually have labels requesting careful handling. A wide range of container configurations, including special drums, boxes, and metal suitcases, may be used.

### 2.A.1.E. Thrust Vector Control Sub-Systems, Usable in the Systems Specified in 1.A., Except as Provided in the Note Below 2.A.1. For Those Designed for Rocket Systems That Do Not Exceed the "Range"/"Payload" Capability of Systems Specified in 1.A.

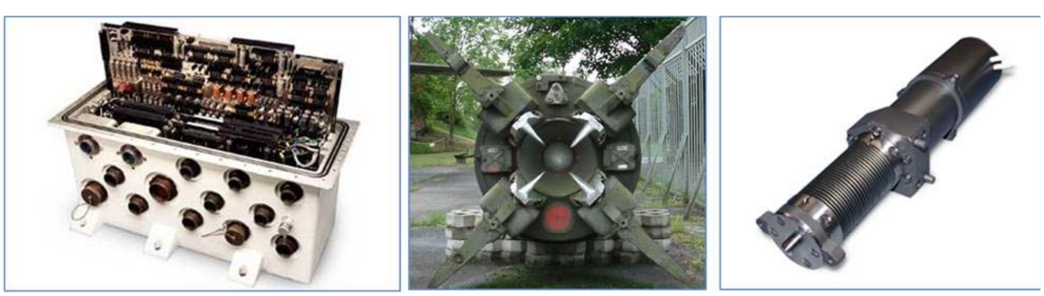


Figure 11: *Left:* A thrust vector control electronics box for use in large launch vehicle applications. (Moog, Inc.) *Center:* Four jet vanes mounted in the rear of a ballistic missile. (Russian military) *Right:* A fine positioning linear actuator designed for use in space applications. (Moog, Inc)

Sourced: Missile Technology Control Regime Annex

Includes the following methods of achieving thrust vector control:

a. Flexible nozzle;
b. Fluid or secondary gas injection;
c. Movable engine or nozzle;
d. Deflection of exhaust gas stream (jet vanes or probes); e.g., Use of thrust tabs.

Actuator rods are cylindrical, approximately 15 cm to 45 cm in length and 3 cm to 8 cm in diameter. Mounting rings and actuator rods are made from high-strength metals such as stainless steel or titanium; actuating valves have stainless steel housings.

The tanks are usually cylindrical composite-overwrapped pressure vessels that vary in size and weight. The gas or liquid feedlines (approximately 1 cm in diameter for smaller engines), control valves, and injectors are often made of stainless steel. Missiles usually use four injectors, sometimes many more. Jet vanes are mounted inside the exhaust nozzle and rotated in response to commands from the missile guidance system to redirect the thrust. They look like small wings usually 30 cm in length and 15 cm in height (sizes vary with engine size). They are made of high-temperature material such as carbon, carbon derivatives, or refractory materials such as tungsten.

Gimbal rings are usually 15 cm to 50 cm in diameter and may be shipped as an assembly (double rings) in an appropriately sized aluminum shipping container with a contoured interior. Actuator rods and valves look like commercial rods and valves. Valves are packaged inside plastic bags for protection against abrasive particles. Because these items can be rather heavy, they are shipped secured in robust containers made of metal or wood. Gas or fluid injection tanks are packaged like commercial products such as propane tanks. Injectors and valves are usually packaged like any piece of expensive equipment in padded containers, and in plastic bags to prevent contamination.

**2.A.1.F. Weapon Or Warhead Safing, Arming, Fuzing, and Firing Mechanisms, Usable in the Systems Specified in 1.A., Except as Provided in the Note Below 2.A.1. For Those Designed For Systems Other Than Those Specified in 1.A.**

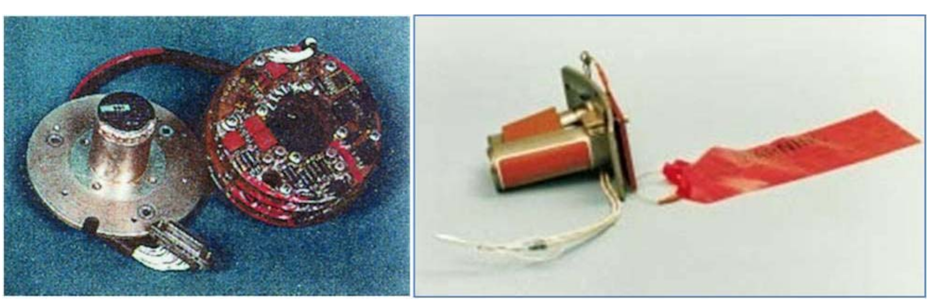


**Figure 13:** ***Left: An RV SAFF system accelerometer with its associated electronics. Right: A missile fuze with safety plate and*** **warning label. (Kaman Aerospace Corporation)**



Sourced: Missile Technology Control Regime Annex Handbook - 2010

Missile SAFF systems and packages are not obtained as a single unit; instead, they are assembled from individual components and subsystems. These components are generally small, aluminum-housed packages with input/output electrical connectors. Simple fuzes are usually housed in aluminum cylinders ranging in diameter from 1 cm for crush fuzes to several centimeters for contact fuzes. Higher technology fuzing systems may involve sophisticated instruments such as accelerometers or active radar transmitters and antennas.

Like most electronics, SAFF systems are shipped in cushioned containers, some of them special, air-tight containers to protect the systems from moisture. A wide range of suitable container configurations, including special drums, boxes, and metal suitcases, may be used.

# ITEM 2: COMPLETE SUBSYSTEMS USABLE FOR COMPLETE DELIVERY SYSTEMS

2.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**2.B.1. "Production Facilities" Specially Designed For The Subsystems Specified In 2.A.**

**2.B.2. "Production Equipment" Specially Designed For The Subsystems Specified In 2.A.**

Each subsystem production facility must contain specialized equipment, jigs, fixtures, molds, dies, and mandrels that are used to manufacture the subassembly's components and subcomponents, assemble them and test the subassembly.

Equipment used to build solid propellant rocket motors includes metalworking machinery, tools for grinding, filtering, and mixing propellant; molds or mandrels to form the motor core or burning surface; devices for fabricating and pyrolizing motor nozzles; and equipment to test the thrust vector control system on the completed motor. Facilities may also contain winding equipment for covering motor cases with composite fiber materials.

# ITEM 2: COMPLETE SUBSYSTEMS USABLE FOR COMPLETE DELIVERY SYSTEMS

2.C. MATERIALS S/2012/947 Category 1

No further information.

# ITEM 2: COMPLETE SUBSYSTEMS USABLE FOR COMPLETE DELIVERY SYSTEMS

2.D. SOFTWARE S/2012/947 Category 1

**2.D.1. "Software" specially designed or modified for the "use" of "production facilities" specified in 2.B.1.**

Typically this software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs and documents can contain this software and data.

**2.D.2. "Software" specially designed or modified for the "use" of rocket motors or engines specified in 2.A.1.c.**

Typically this software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs and documents can contain this software and data.

**2.D.3. "Software," specially designed or modified for the "use" of "guidance sets" specified in 2.A.1.d.**

Typically this software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs and documents can contain this software and data.

**2.D.4. "Software" specially designed or modified for the "use" of subsystems or equipment specified in 2.A.1.b.3.**

Typically this software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs and documents can contain this software and data.

**2.D.5. "Software" specially designed or modified for the "use" of systems in 2.A.1.e.**

Typically this software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this software and data.

**2.D.6. "Software" specially designed or modified for the "use" of systems in 2.A.1.f**

Typically this software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this software and data.

## ITEM 2: COMPLETE SUBSYSTEMS USABLE FOR COMPLETE DELIVERY SYSTEMS

2.E. TECHNOLOGY S/2012/947 Category 1

**2.E.1. "Technology," in accordance with the General Technology Note, for the "development," "production" or "use" of equipment or "software" specified in 2.A., 2.B., or 2.D.**

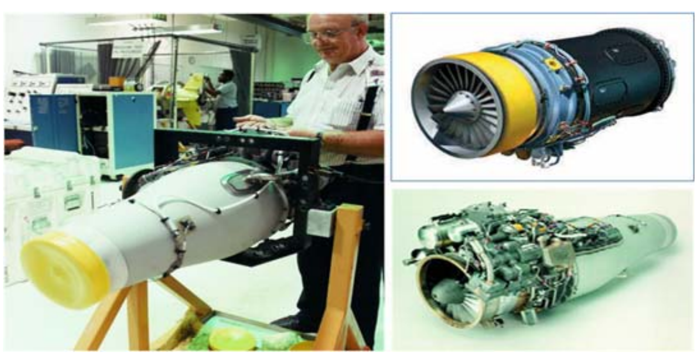
## ITEM 3: PROPULSION COMPONENTS AND EQUIPMENT

3.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**3.A.1. Turbojet and Turbofan Engines, as Follows:**

**A. Engines Having Both of the Following Characteristics:**

1. **"Maximum Thrust Value" Greater Than 400 N (Achieved Un-Installed) Excluding Civil Certified Engines with a "Maximum Thrust Value" Greater Than 8.89 Kn (Achieved Un-Installed)**
2. **Specific Fuel Consumption of 0.15 Kg N-1 H-1 or Less (At Maximum Continuous Power at Sea Level Static and Standard Conditions)**



**(May 2005) Figure 1: Left: A small turbofan engine for a cruise missile on its checkout stand. (MTCR Equipment, Software, and Technology Annex Handbook, Third Edition (May 2005) Top right: A turbofan used to power a HALE UAV. (Rolls Royce Group, plc) Bottom right: A small turbofan engine for a cruise missile. (Williams International)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

The basic turbine engine is cylindrical and measuring less than 1 m in length and 0.5 m in diameter. Numerous accessories such as an alternator, hydraulic pump, fuel pump, and metering valve, along with associated plumbing and wiring, are visible on the outside of the engine. Small fuel efficient engines typically weigh 30 kg to 130 kg; larger engines have diameters of around 1 m and are 3 m in length. Engine parts are manufactured from a number of different materials, both metallic and non-metallic in composition. Common metallic materials include aluminum, steel, titanium, and special alloys. Non-metallic materials such as Teflon, nylon, carbon, and rubber are used for sealing and insulation.

Covering plates are attached over the engine inlet and exhaust, and secured by adhesive tape. The engine is covered with protective paper, and desiccant bags are taped to the engine wrap. The engine is wrapped in corrugated cardboard, inserted into a polyethylene bag, lowered into the shipping crate, and rested on foam blocks. The box is then filled with foam and sealed.

**3.A.2. Ramjet/Scramjet/Pulse Jet/'Combined Cycle Engines, Including Devices to Regulate Combustion, and Specially Designed Components Therefor, Usable in the Systems Specified in 1.A. or 19.A.2.**

**A large ramjet engine. (March Field Air Museum)**

**A modern pulsejet engine with a rearward facing intake. (Thermojet)**

**Left: A fuel manifold and centrifugal fuel injector assembly for a ramjet engine. (Kaiser Marquardt) Center: Various aerodynamic grids used to straighten the flow of air into a ramjet engine. (Kaiser Marquardt) Right: A fuel management system for a ramjet engine. (Kaiser Marquardt)**

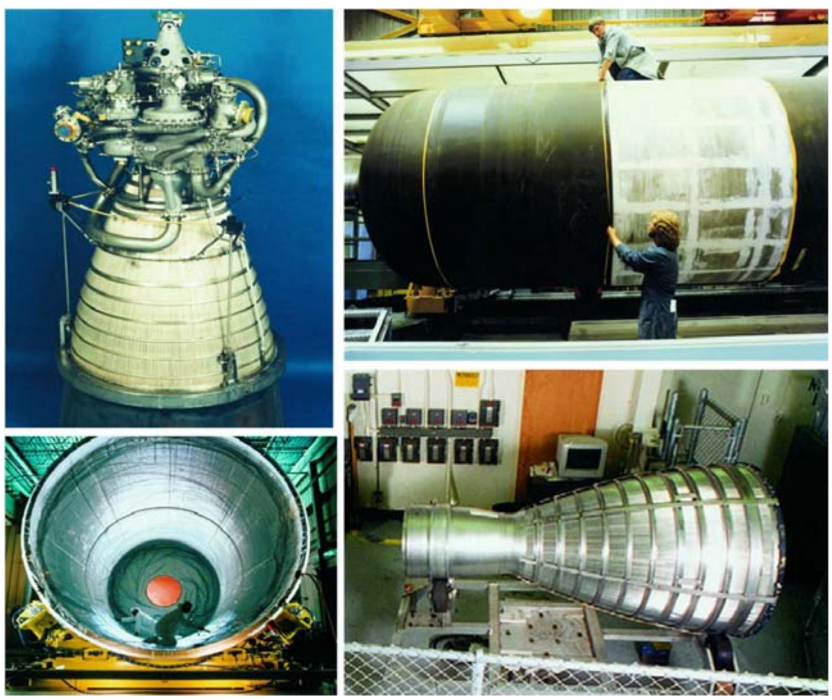
These engines often resemble a metallic pipe with a conical plug in the inlet to control the air flow and a flared conical nozzle on the opposite end. A typical ramjet for missile use can measure 2 m to 4.5 m in length and 0.3 m to 1.0 m in diameter, and weigh up to 200 kg. A scramjet may look like a simple metallic box with sharp inlets. Pulsejets are characterized by their long cylindrical resonator cavity connected to a bulbous control mechanism towards the front.

These engines are packaged like turbojet and turbofan engines covered in 3.A.1.; however, they are most likely to be shipped in wooden or metal crates.

## 3.A.3. Rocket Motor Cases, "Insulation" Components And Nozzles Therefor, Usable in The Systems Specified In 1.A. or 19.A.1.

**of mission platforms, including the first, second and third stage rocket stages of space launch vehicles. (ATK) Right: A rocket motor – installed in a rocket case – which functions as the motor in the third-stage of a launch vehicle. (ATK)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010



**Top left: An engine with a large, regeneratively cooled nozzle. (MTCR Equipment, Software and Technology Handbook, Third edition (May 2005)) Bottom left: Installation of insulation inside a filament wound rocket motor case. (Thiokol Corp.) Top right: A rocket motor case under inspection after application of the thermal insulation. (Fiat Avio) Bottom right: Side view of a regeneratively cooled nozzle. (Boeing)**

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.

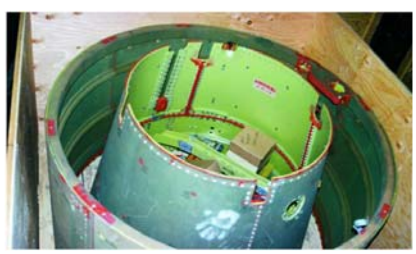
A rocket motor case is a large, steel or composite-filament-wound cylinder with spheroidal or ellipsoidal domes at either end. A motor case for an Item 2.A.1.c. rocket motor typically would be larger than 4 m in length and 0.5 m in diameter. Each of the domes usually has a hole; the small hole at the front end is for the igniter or other internal motor hardware, and the large hole at the back end is for the nozzle. The shape of a rocket nozzle is either similar to an hourglass (convergent-divergent) or conical extending rearward from the narrow throat section at the aft end of the solid rocket motor.

Rocket motor cases are shipped in large wooden or metal crates that contain foam packing or other material to protect them from shock during shipment. Case liners are not likely to be shipped or transferred separately. Insulation material is shipped on large rolls up to 1 m in width and 0.5 m in diameter and sealed in boxes. Shipping containers for rocket nozzles are of two types, depending on nozzle size. Small nozzles with an exit diameter no greater than 50 cm have tailored containers, even metallic cases. Larger nozzles usually have tailored shipping containers built from wood or fiberglass. Protective plastic wraps may also be used, depending on the environmental control capability of the shipping container.

**3.A.4. Staging Mechanisms, Separation Mechanisms, and Interstages Therefor, Usable in the Systems Specified in 1.A.**

**A typical rocket interstage section. (ATK)**

**A selection of explosive bolts designed for use in space launch vehicles and**



**Two interstages in their shipping container. (Ibid)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

An interstage is a conical or cylindrical structure usually manufactured from graphite composite that has the same outside diameter as the rocket stages it connects.

Explosive bolts look like large machine bolts, but with a housing section at the head end. Typically, they measure 7 cm to 10 cm in length and 1 cm to 2.5 cm in diameter, and weigh 50 g to 75 g.

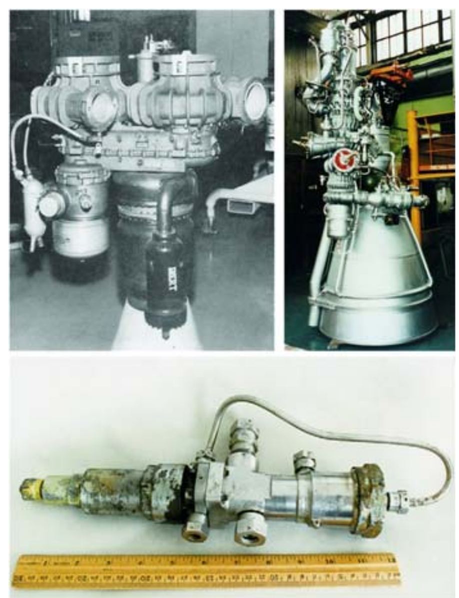
Explosive bolts are shipped in simple cardboard boxes with ample internal foam or other packing to mitigate the effects of shocks. Properly shipped boxes are marked with “Danger-Explosive” or “Danger-Ordnance” symbols and are shipped under restrictions governing explosive materials. Flexible Linear Shaped Charges (FLSC) are usually shipped in varying lengths in lined and protected wooden boxes.

They should be marked with the same “Danger” labels as they are subject to the same shipping restrictions as any ordnance. Ball locks can be packaged and shipped without ordnance restrictions and have no distinguishing features or labels on their packaging. Compression springs are shipped in the uncompressed state in cardboard boxes.

Interstages are usually shipped in tailored wooden containers from the manufacturing facility to the missile stage integrator.

**3.A.5. Liquid And Slurry Propellant (Including Oxidisers) Control Systems, and Specially Designed Components Therefor, Usable in the Systems Specified in 1.A., Designed or Modified to Operate in Vibration Environments Greater Than 10 G Rms Between 20 Hz and 2 Khz.**

***Left: A modern liquid propellant control valve. (Allied Signal Aerospace) Center: A liquid propellant injector plate.*** **(Boeing)** ***Right: A turbopump assembly for a space launch vehicle. (Hamilton Sundstrand)***



***Top Right: A multi-shaft turbopump assembly. (Aerojet) Top (far) right: A single-shaft turbopump. (Aerojet) Bottom:*** **A servo valve from a Scud missile. (MTCR Equipment, Software, and Technology Annex Handbook, Third Edition**

1. The only servo valves and pumps specified in 3.A.5. 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 rpm or with discharge pressures equal to or greater than 7 MPa.
2. Systems and components specified in 3.A.5. may be exported as part of a satellite.

Servo valves look much like on-off valves or line cylinders with tube stubs for propellant inlets and outlets in a metal case. Most valves and housings are made of stainless steel. Turbopumps are usually housed in metal cases and are sized for specific applications. Although they resemble automotive or truck turbochargers, they are much larger and can weigh several hundred kilograms.

The valves are placed in vacuum-sealed plastic bags or sealed plastic bags filled with nitrogen or argon to keep the valves clean and dry. They may sometimes be double bagged and are usually shipped inside a container, often an aluminum case with a contoured foam liner. Small turbopumps are often packaged and shipped in aluminum shipping containers. Depending on size and interface features, a large turbopump may be packaged and shipped in a custom-built shipping crate, with pump supports built in. Turbopumps may also be shipped as a breakdown kit in which separate components are packaged for assembly after receipt.

**3.A.6. Specially Designed Components for Hybrid Rocket Motors Specified in 2.A.1.C. and 20.A.1.B.**

**A hybrid sounding rocket motor. (NASA)**

Sourced: Missile Technology Control Regime Annex Handbook -

A hybrid rocket motor has an oxidizer injector mounted in the top of the high-pressure motor case and a converging/diverging nozzle at the bottom. The injector has valves and piping either from a pressure tank or from a tank and an associated pump. The combustion chamber is usually fabricated either from steel or titanium, which may be black or gray, or from filament-wound graphite or glass epoxy, which is usually yellow or brown. The chamber is lined with thick, solid propellant having one of a variety of configurations and looking like a single cylinder with a hollow center, concentric cylinders, or wagon wheels. Nozzles are made of ablative material, which is often brownish, or high-temperature metals, and they may have high-temperature inserts in their throats.

Hybrid rocket motors may be shipped fully assembled or partially assembled, with tanks and associated hardware packaged separately from the combustion chamber and attached nozzles. Fully assembled units are packaged in wooden crates; components are packaged in wooden crates or heavy cartons.

**3.A.7. Radial Ball Bearings Having All Tolerances Specified in Accordance With Iso 492 Tolerance Class 2 (Or Ansi/Abma Std 20 Tolerance Class Abec-9 or Other National Equivalents), or Better and Having All The Following Characteristics:**

**A. An Inner Ring Bore Diameter Between 12 and 50 mm;**

**B. An Outer Ring Outside Diameter Between 25 and 100 mm; and**

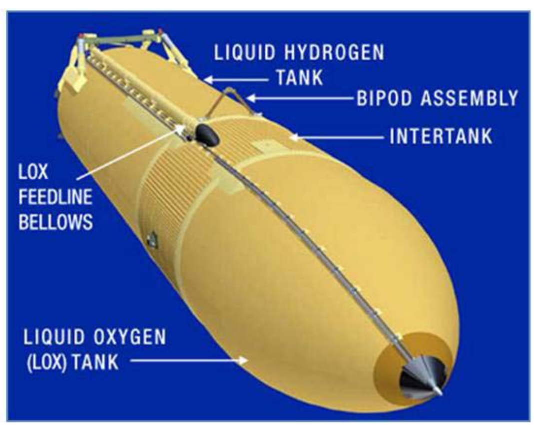
**C. A Width Between 10 and 20 mm.**

Metallic double ring construction, silver in color, with a smooth finish, sometimes polished. The balls are generally visible between the housing races, and the races will rotate freely.

Radial ball bearings are typically packaged in small cardboard boxes with the manufacturer's branding.

**Radial ball bearings manufactured to the ISO 492 tolerance class required by 3.A.7. (GMN)**

**3.A.8. Liquid Propellant Tanks Specially Designed For the Propellants Controlled in Item 4.C. or Other Liquid Propellants Used in the Systems Specified in 1.A.1.**




***Left: A typical liquid propellant tank developed for a range of space applications. (EADS) Right: A diagram of the*** **external tank used by a space vehicle launch engine, showing the separated oxidizer and fuel tanks. (NASA)**

Propellant tanks are usually manufactured in ellipsoidal, hemispherical or domed shapes that vary from 4 m to 10 m in length and 0.5 m to 4 m in diameter. Their external appearance ranges from a silver/aluminum glossy finish associated with high-strength sheet steel, aluminum lithium alloy or titanium from which tanks are manufactured, to a dull brownish color associated with insulation materials to the shiny black or dark grey finish of a graphite or resin overwrap.

Propellant tanks are expensive critical components of all rockets and as such are shipped in specifically designed containers often with shock mounts and internal struts that prevent movement en route. Shipped weight ranges from 240 kg to 320 kg per $m^3$.

### 3.A.9. "Turboprop Engine Systems" Specially Designed for the Systems in 1.A.2. or 19.A.2., and Specially Designed Components Therefor, Having a Maximum Power Greater than 10 kw (Achieved Uninstalled at Sea Level Standard Conditions), Excluding Civil Certified Engines.

***Left: A turboprop engine used to power UAVs controlled under 19.A.2 of the MTCR. (Pratt & Whitney Canada) Center: A turboprop engine used to power a UAV, controlled by 1.A.2 of the MTCR. (Honeywell) Right: A turboshaft engine*** **designed for use in a range of UAV applications. (Rolls Royce, plc)**

For the purposes of Item 3.A.9., a "turboprop engine system" incorporates all of the following:

a. Turboshaft engine; and
b. Power transmission system to transfer the power to a propeller.

Turboprop engines are cylindrical units characterized by an outer casing which may vary in diameter along its length. An intake is generally visible, although not always at the front of the engine. The casing may carry fuel pipes, thermocouples, and various accessory boxes. With its propeller detached, a turboprop engine is harder to identify. The propeller mounting hub is a small diameter disc at the end of the engine with several drilled holes around the circumference and mounting pegs. A turboprop engine capable of producing 900 kW can measure slightly less than 2 m in length and 0.5 m in diameter and may be mistaken for a heater or industrial pump when seen outside an aerospace context. Large turboprop engines may be as long as 3.5 m and weigh more than 1 ton.

A turboprop engine should normally be mounted horizontally on a transit stand or servicing stand which comprises a base (sometimes wheeled) and a cradle supporting the engine at a convenient height for handling, and with provision for lifting by a fork truck. The stand may be fitted with shock attenuating devices for transport. The air intake(s) are covered with blanking plates for protection and the complete engine may be entirely covered by a purpose-made plastic jacket closed by fasteners and buckles. A separate covering is sometimes applied to the propeller when fitted. The engine and propeller may otherwise be covered with plastic sheet. Turboprop engines may be carried in wooden crates or in purpose-built fiberglass or metal containers.

When separated from the engine, propellers are usually carried or stored vertically on a triangular stand, supported at the hub. Under most circumstances, a packaged turboprop engine is likely to be closely accompanied by documents providing its history and maintenance state.

# ITEM 3: PROPULSION COMPONENTS AND EQUIPMENT

3.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**3.B.1. "Production Facilities" Specially Designed for Equipment or Materials Specified in 3.A.1., 3.A.2., 3.A.3., 3.A.4., 3.A.5., 3.A.6., 3.A.8., 3.A.9., or 3.C.**

**3.B.2. "Production Equipment" Specially Designed For Equipment or Materials Specified In 3.A.1., 3.A.2., 3.A.3., 3.A.4., 3.A.5., 3.A.6., 3.A.8., 3.A.9., or 3.C.**

(ROK Doc: Item 36) Injection Molding Machine

Equipment used to build solid propellant rocket motors includes metal-working machinery, possibly continuous filament-case-winding equipment, solid propellant grinding and filtering equipment, equipment for mixing propellant (often in a vacuum), molds or mandrels to form the core or burning surface, nozzle winding and pyrolizing equipment and equipment to test the thrust vector control system on the completed motor.

New equipment or replacement spare parts for these types of facilities are sometimes large and too heavy to be packaged and shipped to the production plant as complete units. Instead, component parts are shipped separately in crates or on protected pallets for onsite assembly. They will be securely fastened to the crate to restrain motion and prevent damage. Smaller jigs may be individually crated or palletized for shipment.

**3.B.3. Flow-Forming Machines, and Specially Designed Components Therefor, Which:**

A. **According to the Manufacturers Technical Specification Can Be Equipped With Numerical Control Units or a Computer Control, Even When Not Equipped With Such Units at Delivery;**
B. **Have More Than Two Axes Which Can Be Co-Ordinated Simultaneously for Contouring Control.**

(ROK Doc: Item 31) Universal Lathe

(ROK Doc: Item 32) Numerically Controlled Lathe

(ROK Doc: Item 33) Milling Machine

(ROK Doc: Item 34) Machining Center


(ROK Doc: Item 44) Flow Forming Machine for Pressure Vessel Fabrication

Larger vertical machines usually require that roller areas, vertical columns and mandrels be boxed separately in wooden crates for shipping. Smaller vertical machines as well as horizontal machines may be shipped in large wooden containers, with the roller arms shipped in the assembled configuration. They will be securely fastened to the containers to preclude movement. The control unit and any hydraulic supply and power units are also boxed separately for shipment.

# ITEM 3: PROPULSION COMPONENTS AND EQUIPMENT

3.C. MATERIALS S/2012/947 Category 1

### 3.C.1. "Interior Lining" Usable for Rocket Motor Cases in the Systems Specified in 1.A. or Specially Designed for Systems Specified in 19.A.1. or 19.A.2.

"Interior lining" suited for the bond interface between the solid propellant and the case or insulating liner is usually a liquid polymer based dispersion of refractory or insulating materials e.g. carbon filled HTPB or other polymer with added curing agents to be sprayed or screeded over a case interior.

The lining of a solid propellant rocket motor is a liquid adhesive used to bond the propellant to the insulation. It is often a 10 mm to 20 mm thick layer of a rubbery material applied to the inside of the motor case then partially cured.

### 3.C.2. "Insulation" Material in Bulk Form Usable for Rocket Motor Cases in the Systems Specified In 1.A. or Specially Designed for Systems Specified in 19.A.1. or 19.A.2.

"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 3.A.3.

Insulation is usually made from elastomers or plastics, and many times the insulation is made of synthetic rubbery material such as ethylene propylene diene monomer (EPDM), polybutadiene, neoprene or nitrile rubber. Insulation material may contain silica or asbestos and resemble a gray or green sheet of rubber.

Internal insulation is a sheet of rubbery substance that is 3 mm to 10 mm thick and up to 1 m in width. It may range in color from black to gray to dark brown.

Insulation material is shipped in large rolls up to 1.0 m in width and 0.5 m in diameter and sealed in boxes. The solid propellant rocket motor case may or may not have internal insulation in place when shipped.

# ITEM 3: PROPULSION COMPONENTS AND EQUIPMENT

3.D. SOFTWARE S/2012/947 Category 1

### 3.D.1. "Software" Specially Designed or Modified for the "Use" of "Production Facilities" and Flow Forming Machines Specified in 3.B.1. or 3.B.3.

(ROK Doc: Item 35)
Numerical Control Devices

This “software” takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this “software” and data.

Magnetic tape, floppy disks, removable hard disks, compact discs and documents containing this “software” are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the “software” is run on the appropriate computer. This “software,” including the documentation, is capable of being electronically transmitted over a computer network.

**3.D.2. “Software” Specially Designed or Modified for the “Use” of Equipment Specified in 3.A.1., 3.A.2., 3.A.4., 3.A.5., 3.A.6., or 3.A.9.**

This “software” takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this “software” and data.

Magnetic tape, floppy disks, removable hard disks, compact discs and documents containing this “software” are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the “software” is run on the appropriate computer. This “software,” including the documentation, is capable of being electronically transmitted over a computer network.

**3.D.3. “Software” Specially Designed or Modified for the “Development” of Equipment Specified in 3.A.2., 3.A.3., or 3.A.4.**

This “software” takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this “software” and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this “software” are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the “software” is run on the appropriate computer. This “software,” including the documentation, is capable of being electronically transmitted over a computer network.

# ITEM 3: PROPULSION COMPONENTS AND EQUIPMENT

3.E. TECHNOLOGY S/2012/947 Category 1

**3.E.1. "Technology," in Accordance With the General Technology Note, for the "Development," "Production" or "Use" of Equipment, Materials or "Software" Specified in 3.A.1., 3.A.2., 3.A.3., 3.A.4., 3.A.5., 3.A.6., 3.A.8., 3.A.9., 3.B., 3.C., or 3.D.**

# ITEM 4: PROPELLANTS, CHEMICALS, AND PROPELLANT PRODUCTION

4.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

No further information.

# ITEM 4: PROPELLANTS, CHEMICALS, AND PROPELLANT PRODUCTION

4.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**4.B.1. "Production Equipment," and Specially Designed Components Therefor, for the "Production," Handling or Acceptance Testing of Liquid Propellants or Propellant Constituents Specified in 4.C.**

Typical components include reactor tanks, condensers, recovery columns, heaters, evaporators, filter assemblies, decanters, chillers, gas separators, and centrifugal pumps.

**4.B.2. "Production Equipment," Other than That Described in 4.B.3., and Specially Designed Components Therefor, for the Production, Handling, Mixing, Curing, Casting, Pressing, Machining, Extruding, or Acceptance Testing of Solid Propellants or Propellant Constituents Specified in 4.C.**

Figure 1: A propellant casting mandrel. (ATK)

**4.B.3.A. Batch Mixers with Provision for Mixing Under Vacuum in the Range of Zero to 13.326 Kpa**

**and with Temperature Control Capability of the Mixing Chamber and Having All of the Following:**
**1. A Total Volumetric Capacity of 110 Litres or More; and**
**2. At Least One Mixing/Kneading Shaft Mounted Off Centre;**

Figure 5: Solid propellant being mixed in a 600-gallon vertical planetary mixer. (Thiokol Corp.)

Appearance (as manufactured): The most distinctive components of a batch mixer are the mixing bowl and the mix blade assembly. The mixing bowls are typically 0.75 m to 1.5 m deep and 1 to 2 m in diameter but may be significantly larger for mixers greater than 450 gallons (1,700 L). They are double-wall constructed; the inner wall is made of highly polished stainless steel, and the outer wall is generally made of cold-rolled steel, sometimes painted. The outer wall has two valves for the connection of inlet/outlet water hoses. The bowl is generally welded to a thick steel rectangular plate with wheels at each corner. The wheels may have grooves so that the bowl assembly can be placed on rails for easier movement.

Sometimes the upper rim of the bowl is a machined flat surface with a large groove to accommodate an O-ring (gasket); other times the mixer head is provided with one or more such grooves.

1. A total volumetric capacity of 110 litres or more; and
2. At least one mixing/kneading shaft mounted off centre;

Mixers may be shipped as complete units or as components. As precision-machined devices, mixer blades are packaged to protect them from damage and the shipping environment. They are likely to be incorporated into the mixer head and frame assembly and securely cradled in shock isolation material blocking during shipping. Mixing bowls are large, heavy pieces of equipment also likely to be shipped in large, strong, wooden crates. They are securely attached to the crates to avoid damage. Crates tend to lack any distinctive features or markings.

**4.B.3.B. Continuous Mixers With Provision for Mixing Under Vacuum in the Range of Zero to 13.326 Kpa and with a Temperature Control Capability of the mixing chamber having any of the Following:**
**1. Two or More Mixing/Kneading Shafts; or**
**2. A Single Rotating Shaft Which Oscillates and Having Kneading Teeth/Pins on the Shaft as Well as Inside the Casing of the Mixing Chamber;**

Fluid energy mills are generally shipped in wooden crates with foam or packing material used to protect them during shipment. The crates are not distinctive.

**4.B.3.C. Fluid Energy Mills Usable for Grinding or Milling Substances Specified in 4.C.**

Fluid energy mills are extremely simple devices with no moving parts. Most are flat, cylindrical devices made of stainless steel and measuring 7 cm to 10 cm in height and 7 cm to 40 cm in diameter. They have an inlet and outlet port for the attachment of ancillary equipment. The interior of the mill is a tubular spiral.

(ROK Doc: Item 41)
Surface Grinding Machine

**4.B.3.D. Metal Powder "Production Equipment" Usable for the "Production," in a Controlled Environment, of Spherical or Atomised Materials Specified in 4.C.2.C., 4.C.2.D., or 4.C.2.E**

Includes:

a. Plasma generators (high frequency arc-jet) usable for obtaining sputtered or spherical metallic powders with organization of the process in an argon-water environment;
b. Electroburst equipment usable for obtaining sputtered or spherical metallic powders with organization of the process in an argon-water environment;
c. Equipment usable for the "production" of spherical aluminium powders by powdering a melt in an inert medium (e.g. nitrogen).

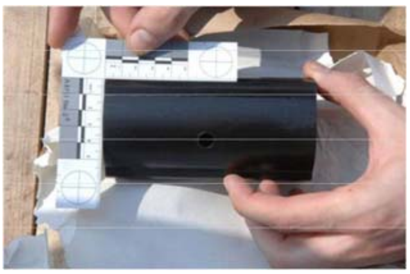
Equipment to produce atomized, spherical metal powder via the method described above is readily assembled from common equipment. The equipment includes a large tank into which the liquid metal is sprayed; a pump attached to the tank to remove the air; a filling system for the inert gas (e.g., tanks and a valve); a heater in which the metal is melted; and a sprayer and nozzle assembly that injects the metal into the tank.

An atomized-metal maker is not shipped as a single unit. Instead, its components are disassembled, packaged, and shipped like most industrial equipment. Smaller pieces are boxed or crated and secured to a pallet. The tank is boxed to protect it from denting. Spray nozzles are packaged separately in protected boxes.

# ITEM 4: PROPELLANTS, CHEMICALS, AND PROPELLANT PRODUCTION

4.C. MATERIALS S/2012/947 Category 1

### 4.C.1. Composite And Composite Modified Double Base Propellants.



Photograph: UN Document S/2012/422
Double-base Propellant Block

**Figure 7: Composite propellants manufactured for use in rocket motors. (Daicel Chemical Industries, Ltd)**

As manufactured "Composite and composite modified double based propellants are hard, rubbery materials resembling automobile tires in texture and appearance. Ingredients such as aluminum or other metal powder gives them a dark gray color; however, other additives may cause the color to vary from red to green to black." (US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-1, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .)

Production countries: Argentina, Brazil, Canada, China, France, Germany, India, Israel, Italy, Japan, Norway, Pakistan, Republic of Korea, Russia, Spain, Sweden, Switzerland, Taiwan, UK, and US.

### 4.C.2. Fuel Substances as Follows:

**a. Hydrazine (CAS 302-01-2) with a concentration of more than 70%;**
Hydrazine (N2H4) is a clear, colorless, hygroscopic liquid with a distinct, ammonia-like odor. (http://www.archchemicals.com/Fed/HDR)

Production countries: China, France, Germany, Russia, UK, and US

Hydrazine products can be stored and shipped in aluminum, 300-series stainless steel, and titanium alloy barrels or tanks. Small purchases are commonly packed in 55-gallon drums; larger orders are shipped in railroad tank cars. Containers of fuel in the hydrazine family are all air purged and are backfilled with an inert gas such as nitrogen to prevent contamination and slow oxidation.

**4.C.2. B. Hydrazine Derivatives as Follows:**

Figure 9: 34-gallon anhydrous hydrazine shipping containers made of 300-series stainless steel. (MTCR Equipment, Software and Technology Annex Handbook, Third Edition (May 2005))

Sourced: Missile Technology Control Regime Annex Handbook - 2010

1. Monomethylhydrazine (MMH) (CAS 60-34-4); Monomethyl hydrazine (CH3NHNH2) is a clear, colorless, hygroscopic liquid. It has an odor typical of relatively short-chain organic amines. (See Arch Chemicals, "Hydrazine," available at www.archchemicals.com/Fed/HDR .)
2. Unsymmetrical dimethylhydrazine (UDMH) (CAS 57-14-7); Unsymmetrical dimethylhydrazine (1,1-dimethylhydrazine) is a clear, colorless hygroscopic liquid. It has an ammonia-like odor which closely resembles that of aliphatic amines. (See Arch Chemicals, "Hydrazine," available at www.archchemicals.com/Fed/HDR .)
3. Hydrazine mononitrate;
4. Trimethylhydrazine (CAS 1741-01-1);
5. Tetramethylhydrazine (CAS 6415-12-9);
6. N,N diallylhydrazine;
7. Allylhydrazine (CAS 7422-78-8);
8. Ethylene dihydrazine;
9. Monomethylhydrazine dinitrate;
10. Unsymmetrical dimethylhydrazine nitrate;
11. Hydrazinium azide (CAS 14546-44-2);
12. Dimethylhydrazinium azide;
13. Hydrazinium dinitrate;
14. Diimido oxalic acid dihydrazine (CAS 3457-37-2);
15. 2-hydroxyethylhydrazine nitrate (HEHN);
16. Hydrazinium perchlorate (CAS 27978-54-7);

17. Hydrazinium diperchlorate (CAS 13812-39-0);
18. Methylhydrazine nitrate (MHN);
19. Diethylhydrazine nitrate (DEHN);
20. 3,6-dihydrazino tetrazine nitrate (DHTN);

**4.C.2.C. Spherical or Spheroidal Aluminium Powder (CAS 7429-90-5) in Particle Size of Less Than 200 X 10-6 m (200 µm) and an Aluminium Content of 97% by Weight or More, if at Least 10% of the Total Weight is Made up of Particles of Less Than 63 µm, According to ISO 2591:1988 or National Equivalents**

As manufactured "Aluminum powder is a gray or dull silver powder. The particle size of most propellant grade aluminum powder ranges from 3 to 100 microns, although larger sizes have been used. The particle shape is more or less spherical." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-5, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

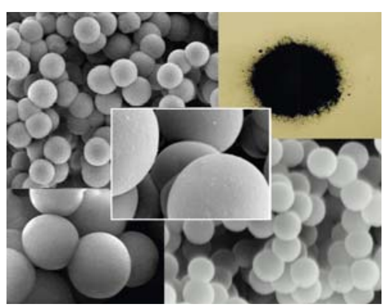
(ROK Doc: Item 54)
Aluminium Powder

Production countries: Canada, China, France, India, Iran, Japan, Pakistan, Russia, and US

Aluminum powder is generally packaged and shipped in steel drums with a capacity of 30 gallons or less. Aluminum powder in a 30-gallon drum weighs approximately 180 kg.

**4.C.2.D. Metal Powders of any of the Following: Zirconium (CAS 7440-67-7), Beryllium (CAS 7440-41-7), Magnesium (CAS 7439-95-4) or Alloys of These, if at Least 90% of the Total Particles by Particle Volume or Weight are Made up of Particles of Less Than 60 µm (Determined By Measurement Techniques Such as Using a Sieve, Laser Diffraction or Optical Scanning), Whether Spherical, Atomised, Spheroidal, Flaked or Ground, Consisting of 97% by Weight or More of any of the Above Mentioned Metals**


(ROK Doc: Item 49)
Magnesium Powder



(ROK Doc: Item 55)
Beryllium Powder

(ROK Doc: Item 56)
Zirconium Powder

As manufactured "Beryllium, magnesium, and zirconium are also gray or dull silver powders." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-5, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

Generally packaged and shipped in steel drums with a capacity of 30 gallons or less.

**4.C.2.E. Metal Powders of Either Boron (CAS 7740-42-8) or Boron Alloys With a Boron Content of 85% or More by Weight, if at Least 90% of the Total Particles by Particle Volume or Weight are Made up of Particles of Less than 60 μm (Determined By Measurement Techniques Such as Using a Sieve, Laser Diffraction or Optical Scanning), Whether Spherical, Atomised, Spheroidal, Flaked, or Ground**

As manufactured "Boron is a dark brown powder. The appearance of boron slurry depends on the liquid to which it is added and the boron particle size; typically, the color is dark brown or black." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-5, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf.

Generally packaged and shipped in steel drums with a capacity of 30 gallons or less.

(ROK Doc: Item 52)
Boron Powder

**4.C.2.F. High Energy Density Materials, Usable in the Systems Specified in 1.A. or 19.A., as Follows:**

1. **Mixed Fuels That Incorporate Both Solid and Liquid Fuels, Such as Boron Slurry, Having a Mass-Based Energy Density of 40 X 106 J/kg or Greater;**
2. **Other High Energy Density Fuels and Fuel Additives (e.g., Cubane, Ionic Solutions, JP-10) Having a Volume-Based Energy Density of 37.5 X 109 J/m³ or Greater, Measured at 20° C and One Atmosphere (101.325 Kpa) Pressure.**

Missile fuels, such as JP 10 and RP 1, may be packaged and shipped in 55-gallon drums. Given the large quantities of RP 1 used in rocket systems, it may also be transported in large 7000 gallon capacity tanker trailers.

**4.C.3. Oxidisers/Fuels as Follows: Perchlorates, Chlorates, or Chromates Mixed With Powdered Metals or Other High Energy Fuel Components.**

"The color of these materials varies with the oxidizer and fuel used. Numerous combinations exist, but the most likely (AP and aluminum powder) are light gray materials with a texture resembling table salt." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-5, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

Rarely shipped in large bulk quantities mixed with a fuel component because of the associated combustion hazard. However, these mixtures are shipped in components such as igniters or in small packages.

**4.C.4.A. Oxidiser Substances Usable in Liquid Propellant Rocket Engines as Follows:**

**1. Dinitrogen Trioxide (CAS 10544-73-7)**

N2O3 is a black liquid at normal atmospheric pressure. Nitric acids and NTO/N2O4 variants are usually stored in stainless steel tanks that have been specially prepared. Aluminum tanks and lines are also compatible with nitric acid. Packages for shipping these chemicals use identifying words, warnings, labels, and symbols. Mixed Oxides of Nitrogen (MON) must be shipped in pressurized containers due to its high vapor pressure and low boiling point.

**2. Nitrogen dioxide (CAS 10102-44-0)/dinitrogen tetroxide (CAS 10544-72-6)**

NO2 is a red-brown gas. N2O4 is a red-brown liquid at room temperature. They are produced in Russia and the US. Nitric acids and NTO/N2O4 variants are usually stored in stainless steel tanks that have been specially prepared. Aluminum tanks and lines are also compatible with nitric acid. Packages for shipping these chemicals use identifying words, warnings, labels, and symbols. MON must be shipped in pressurized containers due to its high vapor pressure and low boiling point.

**3. Dinitrogen pentoxide (CAS 10102-03-1)**

Nitric acids and NTO/N2O4 variants are usually stored in stainless steel tanks that have been specially prepared. Aluminum tanks and lines are also compatible with nitric acid. Packages for shipping these chemicals use identifying words, warnings, labels, and symbols. MON must be shipped in pressurized containers due to its high vapor pressure and low boiling point.

**5. Inhibited Red Fuming Nitric Acid (IRFNA) (CAS 8007-58-7);**

IRFNA is usually stored and shipped in aluminum tanks that have been specially prepared. Stainless steel tanks and lines are also compatible.

**6. Compounds composed of fluorine and one or more of other halogens, oxygen, or nitrogen;**

Fluorine is a pale yellow, highly corrosive, poisonous, gaseous, halogen element. Chlorine is a greenish-yellow gas that is highly irritating and capable of combining with nearly all other elements. Exotic propellants such as chlorine and fluorine are cryogenic liquids and are extremely reactive and toxic. Accordingly, their shipping and handling are tightly regulated. Ordinary metal containers cannot be used to contain them. Super-cooled and pressurized tanks are required to ship in liquid form. Oxygen difluoride (OF2) can be stored at low temperatures in glass-lined, stainless steel tanks that have been specially prepared.

**4.C.4.b. Oxidiser substances usable in solid propellant rocket motors as follows:**

**1. Ammonium perchlorate (AP) (CAS 7790-98-9);**

"AP is a white or, depending on purity, off-white crystalline solid. ADN is a white, waxy, crystalline solid that may appear as thin platelets or small round pills. HMX and RDX are white crystalline materials that resemble very fine table salt." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-10, available at http://www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

Production countries: Brazil, China, France, India, Japan, Russia, UK, and US (ADN has only been produced in Russia, Sweden, and US)

AP is usually packaged and shipped in 30 or 55 gallon polyethylene lined drums with oxidizer or explosive symbol markings.

**2. Ammonium dinitramide (ADN) (CAS 140456-78-6);**

ADN is a white, waxy, crystalline solid that may appear as thin platelets or small round pills.

**3. Nitro-amines (cyclotetramethylene-tetranitramine (HMX) (CAS 2691-41-0); cyclotrimethylene-trinitramine (RDX) (CAS 121-82-4);**

HMX and RDX are white crystalline materials that resemble very fine table salt.

HMX and RDX are usually packaged and shipped either in water or alcohol (because in dry form they are prone to explode) in 30 or 55 gallon polyethylene lined drums with oxidizer or explosive symbol markings.

**4. Hydrazinium nitroformate (HNF) (CAS 20773-28-8);**

HNF is a yellow crystalline material that resembles long needles, although further development has produced a granular form.

**5. 2,4,6,8,10,12-Hexanitrohexaazaisowurtzitane (CL-20) (CAS 135285-90-4).**

2,4,6,8,10,12 Hexanitrohexaazaisowurtzitane are crystalline materials.

**4.C.5. a. Carboxy - terminated polybutadiene (including carboxyl - terminated polybutadiene) (CTPB); b. Hydroxy - terminated polybutadiene (including hydroxyl - terminated polybutadiene) (HTPB); c. Glycidyl azide polymer (GAP);**

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"These … polymers are chemicals used as a binder and fuel in solid rocket motor propellant. . . . [As manufactured,] these materials are clear, colorless, and viscous liquids." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, pp. 4-11–4-12, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

Production countries: China, France, India, Japan, Russia, and US

“These liquids are usually shipped in 55-gallon steel drums. The interiors of these drums are usually coated with an epoxy paint or other material to prevent rusting. If the liquids are shipped in stainless steal drums, the coating is not necessary. Smaller or larger containers may be used, depending on quantity being shipped." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-12, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

**4.C.5.d. Polybutadiene - Acrylic Acid (PBAA); e. Polybutadiene - Acrylic Acid - Acrylonitrile (PBAN); f. Polytetrahydrofuran polyethylene glycol (TPEG).**

"[PBAA and PBAN] are chemicals used as a binder and fuel in solid rocket motor propellant. . . . [As manufactured,] these materials are clear, colorless, and viscous liquids." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, pp. 4-11–4-12, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

Production countries: China, France, India, Japan, Russia, and US

"[PBAA and PBAN] are usually shipped in 55-gallon steel drums. The interiors of these drums are usually coated with an epoxy paint or other material to prevent rusting. If the liquids are shipped in stainless steal drums, the coating is not necessary. Smaller or larger containers may be used, depending on quantity being shipped." US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-12, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

**4.C.6.a. Bonding agents as follows:**

**1. Tris (1-(2-methyl)aziridinyl) phosphine oxide (MAPO) (CAS 57-39-6);**

MAPO is a slightly viscous amber liquid. It has a very distinctive acrid odor. BITA is a light yellow, viscous liquid. Tepanol is a dark yellow, viscous liquid. Tepan is much less viscous than Tepanol but identical to it in all other respects including a very strong odor like that of ammonia. US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-13–4-14, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

MAPO is packaged and shipped in standard, 1 to 55 gallon steel cans or drums.

**2. 1,1',1"-trimesoyl-tris(2-ethylaziridine) (HX-868, BITA) (CAS 7722-73-8);**

BITA is a light yellow, viscous liquid; when cooled below 160 °C, BITA is a pale, off white, waxy solid.

BITA is packaged in 1-gallon steel cans which are usually shipped in insulated containers packed with dry ice and stored at 0°C or less in order to maintain its useful shelf life. Tepanol, Tepan, and PAA shipping and storage conditions are identical to BITA.

**3. Tepanol (HX-878), reaction product of tetraethlylenepentamine, acrylonitrile, and glycidol (CAS 68412-46-4);**

Tepanol is a dark yellow, viscous liquid. It has a very strong odor like that of ammonia.

Packaged in 1-gallon steel cans which are usually shipped in insulated containers packed with dry ice and stored at 0°C or less in order to maintain its useful shelf life. Tepanol, Tepan, and PAA shipping and storage conditions are identical to BITA.

**4. Tepan (HX-879), reaction product of tetraethlylenepentamine and acrylonitrile (CAS 68412-45-3);**

Tepan is much less viscous than Tepanol but identical to it in all other respects including a very strong odor like that of ammonia.

Packaged in 1-gallon steel cans which are usually shipped in insulated containers packed with dry ice and stored at 0°C or less in order to maintain its useful shelf life. Tepanol, Tepan, and PAA shipping and storage conditions are identical to BITA.

**5. Polyfunctional aziridine amides with isophthalic, trimesic, isocyanuric, or trimethyladipic backbone also having a 2-methyl or 2-ethyl aziridine group;**

Packaged in 1-gallon steel cans which are usually shipped in insulated containers packed with dry ice and stored at 0° C or less in order to maintain its useful shelf life. Tepanol, Tepan, and PAA shipping and storage conditions are identical to BITA.

**4.C.6.b. Curing reaction catalysts as follows: Triphenyl bismuth (TPB) (CAS 603-33-8);**

Used to polymerize solid rocket motors; that is, they cause the viscous mixture of liquid polymeric substance and other solid propellant ingredients to solidify into a rubbery composite, which adheres to the inner lining or insulator inside the motor case. TPB is a white to light tan crystalline powder. US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-14, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

Production countries: France, Japan, Switzerland, and US

TPB is packed in brown glass containers because of its sensitivity to light. These containers range in capacity from a few grams to 5 kg. When shipped in larger quantities, TPB may be packed in polyethylene bags inside fiber packs or cardboard cartons. US Government, *Missile Technology Control Regime Annex Handbook*, November 10, 2009, p. 4-14, available at www.fas.org/nuke/control/mtcr/text/mtcr_handbook_item4.pdf .

**4.C.6.c. Burning rate modifiers, as follows:**

1. Carboranes, decaboranes, pentaboranes and derivatives thereof;
   Carboranes, decarboranes, pentaboranes, and their derivatives are clear, colorless liquids with no distinct odor.

   All of these materials are shipped in steel drum containers ranging in capacity from 1 gal. to 55 gal.
2. Ferrocene derivatives, as follows:
   a. Catocene (CAS 37206-42-1);
   b. Ethyl ferrocene (CAS 1273-89-8);
   c. Propyl ferrocene;
   d. n-Butyl ferrocene (CAS 31904-29-7);
   e. Pentyl ferrocene (CAS 1274-00-6);

f. Dicyclopentyl ferrocene;
g. Dicyclohexyl ferrocene;
h. Diethyl ferrocene (CAS 1273-97-8);
i. Dipropyl ferrocene;
j. Dibutyl ferrocene (CAS 1274-08-4);
k. Dihexyl ferrocene (CAS 93894-59-8);
l. Acetyl ferrocene (CAS 1271-55-2) / 1,1'-diacetyl ferrocene (CAS 1273-94-5);
m. Ferrocene carboxylic acid (CAS 1271-42-7) 1,1'-Ferrocenedicarboxylic acid (CAS 1293-87-4);
n. Butacene (CAS 125856-62-4);
o. Other ferrocene derivatives usable as rocket propellant burning rate modifiers;

Catocene is a slightly viscous, dark red liquid but appears yellow in a thin film or as a yellow stain on white cloth or paper. Catocene has the chemical formula C27H32Fe2. Catocene, the commercial trade name for 2,2'-bis (ethylferrocenyl) propane, is probably the most widely used ferrocene in the propellant industry.

Ferrocene and its derivates is an orange to yellow powder crystal.

N-butyl ferrocene and other ferrocene derivatives are similar in appearance to Catocene.

Butacene is unique as it is both an HTPB binder and a burn rate modifier. It is a very high-viscosity liquid that resembles a very heavy, dark corn syrup or molasses.

All of these materials are shipped in steel drum containers ranging in capacity from 1 gal. to 55 gal.

**4.C.6.d. Esters and plasticisers as follows:**

**1. Triethylene glycol dinitrate (TEGDN) (CAS 111-22-8)**

Additives to solid rocket propellants used to increase burn rate. Nitrate esters are dense, oily liquids ranging in color from clear to slightly yellow.

Any country has the capability to produce these materials.

Nitrate esters are shipped in 5 to 55 gallon steel drums marked with labels indicating explosives. Except for BTTN, these nitrate esters are shipped undiluted unless the end-user requests that they be shipped diluted with solvent. Because of its sensitivity to shock, BTTN is shipped diluted with either methylene chloride or acetone. When diluted with methylene chloride, BTTN has a sweet odor. When diluted with acetone, it has an odor like that of nail polish. When stabilizers are added the nitrate ester acquires a deep red color.

**2. Trimethylolethane trinitrate (TMETN) (CAS 3032-55-1);**

Additives to solid rocket propellants used to increase burn rate. Nitrate esters are dense, oily liquids ranging in color from clear to slightly yellow.

Nitrate esters are shipped in 5 to 55 gallon steel drums marked with labels indicating explosives. Except for BTTN, these nitrate esters are shipped undiluted unless the end-user requests that they be shipped diluted with solvent. Because of its sensitivity to shock, BTTN is shipped diluted with either methylene chloride or acetone. When diluted with methylene chloride, BTTN has a sweet odor. When diluted with acetone, it has an odor like that of nail polish. When stabilizers are added the nitrate ester acquires a deep red color.

**3. 1,2,4-butanetriol trinitrate (BTTN) (CAS 6659-60-5);**

Additives to solid rocket propellants used to increase burn rate. Nitrate esters are dense, oily liquids ranging in color from clear to slightly yellow.

Nitrate esters are shipped in 5 to 55 gallon steel drums marked with labels indicating explosives. Except for BTTN, these nitrate esters are shipped undiluted unless the end-user requests that they be shipped diluted with solvent. Because of its sensitivity to shock, BTTN is shipped diluted with either methylene chloride or acetone. When diluted with methylene chloride, BTTN has a sweet odor. When diluted with acetone, it has an odor like that of nail polish. When stabilizers are added the nitrate ester acquires a deep red color.

**4. Diethylene glycol dinitrate (DEGDN) (CAS 693-21-0);**

Additives to solid rocket propellants used to increase burn rate. Nitrate esters are dense, oily liquids ranging in color from clear to slightly yellow.

Nitrate esters are shipped in 5 to 55 gallon steel drums marked with labels indicating explosives. Except for BTTN, these nitrate esters are shipped undiluted unless the end-user requests that they be shipped diluted with solvent. Because of its sensitivity to shock, BTTN is shipped diluted with either methylene chloride or acetone. When diluted with methylene chloride, BTTN has a sweet odor. When diluted with acetone, it has an odor like that of nail polish. When stabilizers are added the nitrate ester acquires a deep red color.

**5. 4,5 diazidomethyl-2-methyl-1,2,3-triazole (iso- DAMTR);**

Additives to solid rocket propellants used to increase burn rate. Nitrate esters are dense, oily liquids ranging in color from clear to slightly yellow.

Nitrate esters are shipped in 5 to 55 gallon steel drums marked with labels indicating explosives. Except for BTTN, these nitrate esters are shipped undiluted unless the end-user requests that they be shipped diluted with solvent. Because of its sensitivity to shock, BTTN is shipped diluted with either methylene chloride or acetone. When diluted with methylene chloride, BTTN has a sweet odor. When diluted with acetone, it has an odor like that of nail polish. When stabilizers are added the nitrate ester acquires a deep red color.

**6. Nitratoethylnitramine (NENA) based plasticisers, as follows:**

a. Methyl-NENA (CAS 17096-47-8);

b. Ethyl-NENA (CAS 85068-73-1);
c. Butyl-NENA (CAS 82486-82-6);

Additives to solid rocket propellants used to increase burn rate. Nitrate esters are dense, oily liquids ranging in color from clear to slightly yellow.

Nitrate esters are shipped in 5 to 55 gallon steel drums marked with labels indicating explosives. Except for BTTN, these nitrate esters are shipped undiluted unless the end-user requests that they be shipped diluted with solvent. Because of its sensitivity to shock, BTTN is shipped diluted with either methylene chloride or acetone. When diluted with methylene chloride, BTTN has a sweet odor. When diluted with acetone, it has an odor like that of nail polish. When stabilizers are added the nitrate ester acquires a deep red color.

**7. Dinitropropyl based plasticisers, as follows:**

a. Bis (2,2-dinitropropyl) acetal (BDNPA) (CAS 5108-69-0);
b. Bis (2,2-dinitropropyl) formal (BDNPF) (CAS 5917-61-3);

Additives to solid rocket propellants used to increase burn rate. Nitrate esters are dense, oily liquids ranging in color from clear to slightly yellow.

Nitrate esters are shipped in 5 to 55 gallon steel drums marked with labels indicating explosives. Except for BTTN, these nitrate esters are shipped undiluted unless the end-user requests that they be shipped diluted with solvent. Because of its sensitivity to shock, BTTN is shipped diluted with either methylene chloride or acetone. When diluted with methylene chloride, BTTN has a sweet odor. When diluted with acetone, it has an odor like that of nail polish. When stabilizers are added the nitrate ester acquires a deep red color.

**4.C.6.e. Stabilisers as follows:**

1. 2-Nitrodiphenylamine (CAS 119-75-5)
   In its pure state, 2-NDPA is a bright yellow, crystalline solid. The chemical formula for 2-NDPA is C12H10N2O2. When exposed to light, 2-NDPA turns to a dark orange color.

2. N-methyl-p-nitroaniline (CAS 100-15-2)
   When shipped in small quantities, 2-NDPA and MNA are packaged in brown glass containers because they are sensitive to light. When shipped in larger quantities, they are packaged in polyethylene bags and placed inside fiberpack or cardboard containers.

   MNA is also a bright yellow, crystalline solid. The chemical formula for MNA is C7H8N2O2.

   When shipped in small quantities, 2-NDPA and MNA are packaged in brown glass containers because they are sensitive to light. When shipped in larger quantities, they are packaged in polyethylene bags and placed inside fiberpack or cardboard containers.

# ITEM 4: PROPELLANTS, CHEMICALS, AND PROPELLANT PRODUCTION

4.D. SOFTWARE S/2012/947 Category 1

**4.D.1. "Software" Specially Designed or Modified for the "Use" of Equipment Specified in 4.B. for the "Production" and Handling of Materials Specified in 4.C.**

Typically this software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use, unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network

# ITEM 4: PROPELLANTS, CHEMICALS, AND PROPELLANT PRODUCTION

4.E. TECHNOLOGY S/2012/947 Category 1

**4.E.1 "Technology," in Accordance with the General Technology Note, for the "Development," "Production" or "Use" of Equipment or Materials Specified in 4.B. and 4.C.**

# ITEM 6: PRODUCTION OF STRUCTURAL COMPOSITES, PYROLYTIC DEPOSITION AND DENSIFICATION, AND STRUCTURAL MATERIALS

6.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**6.A.1. Composite Structures, Laminates, and Manufactures Thereof, Specially Designed for Use in the Systems Specified in 1.A., 19.A.1. or 19.A.2. and the Subsystems Specified in 2.A. or 20.A.**

(ROK Doc: Item 68)
Composite

1

Composite structures are packaged much like other structures, with foam or other materials to protect them from surface abrasions or distortions from stress.

**6.A.2. Resaturated Pyrolised (i.e., Carbon-Carbon) Components Having All of the Following:**
**A. Designed for Rocket Systems; and**
**B. Usable in the Systems Specified in 1.A. or 19.A.1.**

Typical carbon-carbon materials designed for rocket systems are black and have a patterned surface as a result of textile reinforcement. Nose tips and rocket nozzles are usually machined from blocks or billets or can be woven to shape.

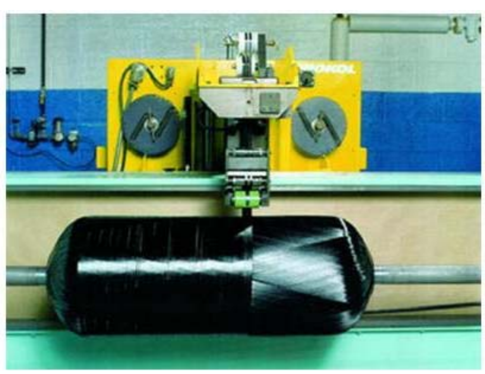
Before machining, blocks of carbon material are rugged enough to be packed in filler and shipped in cardboard boxes. Machined parts require careful packaging because, although resistant to breaking (impact resistant), they can easily be gouged or scraped.

# ITEM 6: PRODUCTION OF STRUCTURAL COMPOSITES, PYROLYTIC DEPOSITION AND DENSIFICATION, AND STRUCTURAL MATERIALS

6.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**6.B.1. Equipment for the "production" of structural composites, fibres, prepregs or preforms, usable in the systems specified in 1.A., 19.A.1. or 19.A.2., as follows, and specially designed components, and accessories therefor:**

**a. Filament winding machines or fibre placement machines, of which the motions for positioning, wrapping and winding fibres can be co-ordinated and programmed in three or more axes, designed to fabricate composite structures or laminates from fibrous or filamentary materials, and co-ordinating and programming controls**



**Tabletop filament-winding machine. (Thiokol Corp.)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Examples of components and accessories for the machines specified in 6.B.1. are moulds, mandrels, dies, fixtures, and tooling for the preform pressing, curing, casting, sintering, or bonding of composite structures, laminates, and manufactures thereof.

Filament winders used to manufacture parts 10 cm in diameter measure about 1 m x 2 m x 7 m and can fit on a tabletop. Winders for large components, such as large rocket motor segments, are approximately 3 m diameter and 8 m in length and weigh several tons.

The size of filament winding machines dictates their packaging. Smaller machines are crated in shock-absorbing containers or attached to cushioned pallets isolated from other packages. Larger machines are disassembled for shipping and reassembled on-site, and their components are packaged separately in crates or on pallets.

### 6.B.1.B. Tape-Laying Machines of Which the Motions for Positioning and Laying Tape and Sheets Can Be Co-Ordinated and Programmed in Two or More Axes, Designed for the Manufacture of Composite Airframes and Missile Structures

**An automated tape-laying machine head. (Automated Dynamics)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

The size of tape-laying machines varies with the size of the required parts. Machines are either operator assisted or Computer Numerically Controlled (CNC). CNC machines have a keyboard to input data for the desired composite lay-ups. The flatbed, which is the dominant feature of the machine, measures 1 m to 2 m in length for the manufacture of small parts and 10 m for very large parts. The weight of large machines with a steel table and gantry could be 1000 to 2000 metric tons.

The size of tape-laying machines dictates their packaging. Smaller machines are crated in shock-absorbing containers or attached to cushioned pallets isolated from other packages. Larger machines are disassembled for shipping and reassembled on-site, and their components are packaged separately in crates or on pallets.

**6.B.1.C. Multi-Directional, Multi-Dimensional Weaving Machines or Interlacing Machines, Including Adapters and Modification Kits for Weaving, Interlacing or Braiding Fibres to Manufacture Composite Structures**

**Left: A 144 carrier overhead gantry braiding machine. (Wardwell Braiding Machine Co.) Right: Prototype of a multidirectional weaving machine under development. (MD Fibertech Corp)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

6.B.1.c. does not control textile machinery not modified for the end-uses stated.

A weaving machine has a work area on a rotating table with a network of rods penetrating pierced plates around which the fiber is woven. The work area is surrounded by spooled fiber dispensers and by weaving and lacing needles. The drive motors, cams, and push rods that do the weaving are also mounted on the main frame of the machine.

Weaving machines used to make small parts might measure 2 m in length and 1 m in width. Those used to make large parts might be 10 m long if arranged horizontally or 10 m high if arranged vertically.

Braiding machines can be either floor-mounted or have an overhead gantry supporting the spindle on which the preform is made.

The packaging of weaving machines depends on their size. Smaller machines can be completely encased in packing crates. The components of larger machines are disassembled for shipping and reassembled on-site, and are packaged separately in crates or on pallets. It is likely that one large crate contains the machine frame. All components are suitably protected from shock and vibration during transportation and handling.

**6.B.1.D. Equipment Designed or Modified for the Production of Fibrous or Filamentary Materials as Follows:**

**1. Equipment for Converting Polymeric Fibres (Such as Polyacrylonitrile, Rayon, or Polycarbosilane) Including Special Provision to Strain the Fibre During Heating**

The most noticeable items are the many precision rollers and the mechanisms for their control. The rollers are typically 8 cm to 20 cm in diameter by 30 cm to 120 cm long, with their size related to the ovens in which they are to be used. A typical fiber-drawing oven system has many rollers and isolated heating zones in the furnace. The size of the equipment varies widely.

The ovens, furnaces, and processing equipment needed to produce carbon fibers vary in packaging depending on their size, weight, and sensitivity to environmental factors. Generally, laboratory versions of the equipment can be completely crated and shipped by rail or truck. Larger furnaces designed for commercial use generally have to be shipped in component units and assembled on-site. However, some of the furnaces can be of such large diameter that they must be specially handled as oversize cargo. The weight for these larger furnaces approaches 1000 metric tons or more.

**6.B.1.D.2. Equipment Designed or Modified for the Production of Fibrous or Filamentary Materials as Follows:**

**2. Equipment for the Vapour Deposition of Elements or Compounds on Heated Filament Substrates**

Some are long tubes with seals at each end that permit the passage of filaments but not gases. Others are large chambers, 2 m to 3 m on a side, with room enough to hold the filament spools, filament guide equipment including spreading and tensioning rollers, a hot zone if needed, and the reactant gases. Because of this variation, the only standardized and readily recognizable parts of the equipment are the gas supply system, a large power supply, vacuum pumps, and possibly the instrumentation that controls the temperature. In all cases, the power supplies are of substantial size and weight, typically greater than 0.6 m x 0.9 m x 1.5 m with water inlets for cooling, pumping, and safety cutoffs. PACVD equipment looks like a conventional CVD or PVD system except that it has a radio-frequency (RF) power supply to produce the plasma.

Packaging varies depending on size, weight, and sensitivity to environmental factors. Generally, laboratory versions of the equipment can be completely crated and shipped by rail or truck. However, even laboratory versions generally have components packaged separately so that the textile spools, motors, and special glassware can receive adequate protection. Larger systems designed for commercial use are usually shipped as subassemblies or components and assembled on-site.

**6.B.1.D.3. Equipment Designed or Modified for the Production of Fibrous or Filamentary Materials as Follows:**

**3. Equipment for the Wet-Spinning of Refractory Ceramics (Such as Aluminium Oxide)**

A major component of wet-spinning equipment is the cylindrical chemical reaction chamber. Although glassware is acceptable for laboratory and prototype wet-spinning equipment, stainless steel or glass-lined reaction chambers are used for production grade wet-spinning equipment. Typically, the chamber is vertically oriented and tapered at the bottom, where the dies that extrude the filaments are located. Other equipment associated with the chemical reaction chamber includes a cylindrical vessel (much longer than its diameter) that contains the chemical slurry from which the filament is produced; a pressure gauge and gas exhaust line attached to the vessel; a tube assembly containing sections of both fixed and rotating glass tubes; a ball valve connected to the fixed glass tube; a motor and controller for driving the rotating tube; and a snubber roller and take-up reel for the finished filaments.

Packaging is typical of any similarly sized industrial equipment. Generally, fully assembled laboratory versions of the equipment can be crated and shipped by rail or truck. Components of larger equipment designed for commercial use are shipped in separate boxes or crates and assembled on-site.

**6.B.1.E. Equipment Designed or Modified for Special Fibre Surface Treatment or for Producing Prepregs and Preforms, Including Rollers, Tension Stretchers, Coating Equipment, Cutting Equipment and Clicker Dies.**

**A prepreg machine constructed by the Composite Materials Group for the production of prepreg materials using fibers and resins. (Katholieke Universiteit Leuven)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

A laboratory bench with small rollers and heater guns is the only equipment needed to treat or prepreg fiber on a prototype basis.

The packaging of the equipment, with the exception of small laboratory apparatus, usually requires that components be shipped separately and assembled on-site. The vats for chemicals can be packaged in simple corrugated boxes, but the rollers, which have a precision or special surface finish to avoid damaging the filaments, need cushioning and rigid mounting in substantial crates. Electrical control equipment, if included, will be packaged like other fragile electronics.

**6.B.2. Nozzles Specially Designed for the Processes Referred to in 6.E.3.**

Nozzle dimensions are approximately half the width of the furnace. Small nozzles are typically made of graphite because it is inexpensive, easily replaced, and lightweight (approximately 0.5 kg to 2.5 kg). Larger nozzles for production furnaces are often made of metal, require water-cooling, may have integral attachment flanges, and weigh upwards of 25 kg. The larger, more complex, water-cooled nozzles are up to 1.5 m long, with their tubular portion 20 cm in diameter.

Packaging for the nozzle and pyrolytic deposition equipment is suitable for preventing damage to a highly durable pipe with somewhat fragile valves and fittings. Typically, several nozzles are shipped together in well protected packaging separate from any large furnace shell.

**6.B.3. Isostatic Presses Having All of the Following Characteristics:**
**A. Maximum Working Pressure Equal to or Greater than 69 Mpa;**
**B. Designed to Achieve and Maintain a Controlled Thermal Environment of 600° C or Greater; and**
**C. Possessing a Chamber Cavity With an Inside Diameter of 254 mm or Greater.**

(ROK Doc: Item 40)
Hydraulic Press

***Left: A laboratory sized isostatic press. (ESPI) Right: A laboratory sized hot isostatic press. (Abra Fluid AG)***

Sourced: Missile Technology Control Regime Annex Handbook - 2010

a. Maximum working pressure equal to or greater than 69 MPa;
b. Designed to achieve and maintain a controlled thermal environment of 600° C or greater; and
c. Possessing a chamber cavity with an inside diameter of 254 mm or greater.

A typical laboratory-size system has three main components: a pressure chamber, a high-pressure generator, and a control console. The pressure chamber is usually a vertical, thick-walled cylinder with a removable, high-pressure closure, or plug, at the upper end. The components of an isostatic press system are likely to be shipped separately and assembled at the final work destination. Packaging varies with the requirements of the purchaser, but wooden pallets and crates with steel banding and reinforcement are common. Larger chambers are very heavy because of the thick walls and may be packaged in a cylindrical wooden crate with wide steel banding.

**6.B.4. Chemical Vapour Deposition Furnaces Designed or Modified for the Densification of Carbon-Carbon Composites.**

***Left: A large scale custom CVD furnace which inductively heats graphite to temperatures in the 2800 °C range.*** **(CVI)**

Sourced: Missile Technology Control Regime Annex

CVD furnaces are large, double-walled, cylindrical vessels with gas-tight closures. Typical CVD furnaces are large because they house an internal heat zone, electrically driven heaters, and insulation. Furnaces smaller than 1.5 m in height and 1 m in diameter are considered laboratory scale and are barely able to process a single nose tip or rocket nozzle insert. Process production sizes are larger than 2 m in height and 2 m in diameter. These furnaces have several ports: at least one large port for power feeds, others for instrumentation, and, when temperatures are measured by optical or infrared pyrometers, one or more view-ports.

Packaging consists of pallets and crates for each part because of the large size and weight of the equipment.

**6.B.5. Equipment and Process Controls, Other Than Those Specified in 6.B.3. or 6.B.4., Designed or Modified for Densification and Pyrolysis of Structural Composite Rocket Nozzles and Re-Entry Vehicle Nose Tips.**

Larger pieces of equipment may be shipped as components, while smaller items may be shipped assembled. These items are usually shipped in crates or on pallets in a similar manner to other industrial equipment. Process controls (including technical data) are shipped like other information on paper, magnetic, or other media. Software can be transferred on disks, CD-ROMs, DVDs etc., or over networks. Software and technical data may be included in the shipping containers with its respective equipment.

# ITEM 6: PRODUCTION OF STRUCTURAL COMPOSITES, PYROLYTIC DEPOSITION AND DENSIFICATION, AND STRUCTURAL MATERIALS

6.C. MATERIALS S/2012/947 Category 1

**6.C.1. Resin Impregnated Fibre Prepregs and Metal Coated Fibre Preforms, for the Goods Specified in 6.A.1., Made Either With Organic Matrix or Metal Matrix Utilising Fibrous or Filamentary Reinforcements Having a Specific Tensile Strength Greater Than 7.62 X 104 m and a Specific Modulus Greater Than 3.18 X 106 m.**

**Prepreg material used in the manufacture of lightweight, high-strength composite aerospace and defense structures. (Ibid)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

The only resin impregnated fibre prepregs specified in 6.C.1. are those using resins with a glass transition temperature (Tg), after cure, exceeding 145° C as determined by ASTM D4065 or national equivalents.

1. In Item 6.C.1. 'specific tensile strength' is the ultimate tensile strength in N/m2 divided by the specific weight in N/m3, measured at a temperature of (296 ± 2)K ((23 ± 2)° C) and a relative humidity of (50 ± 5)%.
2. In Item 6.C.1. 'specific modulus' is the Young's modulus in N/m2 divided by the specific weight in N/m3, measured at a temperature of (296 ± 2)K ((23 ± 2)° C) and a relative humidity of (50 ± 5)%.

The fibrous materials discussed here must be refrigerated after impregnation with resin. To maintain sufficiently low temperatures during shipment, the prepreg material is packed in special containers for dry ice cooling, or it is shipped in mechanically refrigerated cargo containers.

**6.C.2. Resaturated Pyrolised (i.e., Carbon-Carbon) Materials Having All of the Following:**

**A. Designed for Rocket Systems; and**

**B. Usable in the Systems Specified in 1.A. or 19.A.1.**

(ROK Doc: Item 51)
Carbon-carbon Material

Typical carbon-carbon materials designed for rocket systems are black and have a patterned surface as a result of textile reinforcement. Nose tips and rocket nozzles are usually machined from blocks or billets.

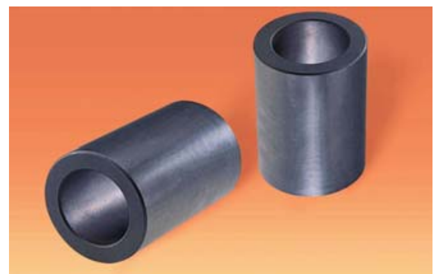
Before machining, blocks of carbon-carbon material are rugged enough to be packed in filler and shipped in cardboard boxes. Machined parts require careful packaging because, although the material is resistant to breaking (impact resistant), they can easily be gouged or scraped.

**6.C.3. Fine Grain Graphites with a Bulk Density of at Least 1.72 g/cc Measured at 15° C and Having a Grain Size of 100 X 10-6 m (100 μm) or Less, Usable for Rocket Nozzles and Re-Entry Vehicle Nose Tips, Which Can Be Machined to Any of the Following Products:**

**A. Cylinders Having a Diameter of 120 mm or Greater and a Length of 50 mm or Greater;**

**B. Tubes Having an Inner Diameter of 65 mm or Greater and a Wall Thickness of 25 mm or Greater and a Length of 50 mm or Greater; or**

**C. Blocks Having a Size of 120 mm X 120 mm X 50 mm or Greater.**



(ROK Doc: Item 53) Graphite Tubes

These materials are packaged to protect their delicate surfaces and often to prevent any surface contamination. Typically, parts are placed in plastic bags or containers, which are packaged in materials normally used for fragile parts (i.e., bubble wrap, foam, etc.).

**6.C.4. Pyrolytic or Fibrous Reinforced Graphites Usable for Rocket Nozzles and Re-Entry Vehicle Nose Tips Usable in Systems Specified in 1.A. or 19.A.1.**

In powder form, it is dark grey to black in color. In manufactured parts the color is black with the extent of glossiness dependent on the machining process. Surfaces are pitted.

The danger of cracking to which pyrolitic graphite is susceptible requires that it is well packaged, with components usually placed in plastic bags or containers, surrounded by bubble wrap or foam.

**6.C.5. Ceramic Composite Materials (Dielectric Constant Less Than 6 at any Frequency from 100 mhz to 100 ghz) for Use in Missile Radomes Usable in Systems Specified in 1.A. or 19.A.1.**

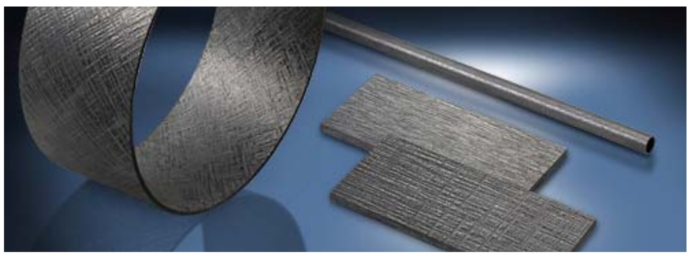
A block of three-dimensional (3-D) silica-silica from which antenna windows are made may have a textile pattern evident on all surfaces. This material is often covered with a clear protective coating as a barrier to moisture. A siliconcarbide reinforced ceramic has the same pattern but is dark gray or black. All of these ceramic materials are very hard, much harder than other composites, and have a surface patterned like the textile reinforcement. They may be found in virtually any size between 1 mm discs and 50 cm cubes, which can be cut and ground to the required configuration by diamond tooling.

Because of their high cost and brittleness, these composites are packed in shock-absorbent materials. Since silica-silica material is also hygroscopic (i.e., it absorbs water), it is also packed in sealed bags of either mylar or other plastic, often with some type of a desiccant in the larger packing container. Some shippers also fill the sealed bags with dry nitrogen to protect the material from water absorption.

**6.C.6. Silicon-Carbide Materials as Follows:**

**A. Bulk Machinable Silicon-Carbide Reinforced Unfired Ceramic Usable for Nose Tips Usable in Systems Specified in 1.A. or 19.A.1.;**

**B. Reinforced Silicon-Carbide Ceramic Composites Usable for Nose Tips, Re-Entry Vehicles, Nozzle Flaps, Usable in Systems Specified in 1.A. or 19.A.1.**



(ROK Doc: Item 50) Silicon Carbide composite

The three-dimensional silica-silica used to make antenna windows may have a textile pattern on all surfaces. To prevent against moisture, this material is often protected with a clear coating. Ceramics reinforced by silicon-carbide will exhibit the same surface pattern but the color is black or dark gray. Size ranges from 1 mm discs to 50 cm cubes that can subsequently be cut or tooled to the desired shape.

Silicon-carbide is a brittle compound, and thus shock-absorbent substances are used to pack silicon-carbide composites. Sealed bags or other plastics are used to prevent exposure to moisture during shipping. Larger shipments often contain desiccants. Sealed bags are sometimes filled with dry nitrogen to provide additional protection against water absorption.

**6.C.7. Materials for the Fabrication of Missile Components in the Systems Specified in 1.A., 19.A.1., or 19.A.2, as Follows:**

**A. Tungsten and Alloys in Particulate Form With a Tungsten Content of 97% by Weight or More and a Particle Size of 50 X10-6 m (50 µm) or Less;**

**B. Molybdenum and Alloys in Particulate Form With a Molybdenum Content of 97% By Weight or More and a Particle Size of 50 X10-6 m (50 µm) or Less;**

**C. Tungsten Materials in the Solid Form Having All of The Following:**

   **1. Any of the Following Material Compositions:**

      **I. Tungsten and Alloys Containing 97% by Weight or More of Tungsten;**

II. **Copper Infiltrated Tungsten Containing 80% by Weight or More of Tungsten; or**
III. **Silver Infiltrated Tungsten Containing 80% by Weight or More of Tungsten; and**

2. **Able to Be Machined to Any of the Following Products:**
   I. **Cylinders Having a Diameter of 120 mm or Greater and a Length of 50 mm or Greater;**
   II. **Tubes Having an Inner Diameter of 65 mm or Greater and a Wall Thickness of 25 mm or Greater and a Length of 50 mm or Greater; or**
   III. **Blocks Having a Size of 120 mm x 120 mm x50 mm or Greater.**

(ROK Doc: Item 48) Tungsten Alloy


(ROK Doc: Item 58) Tungsten Powder

Tungsten, molybdenum, and their alloys as spherical or atomized particles look like many other powder metallurgy products. The particles have a metallic sheen and flow freely because of their spherical shape. Tungsten in solid form is a silvery-white lustrous metal that tarnishes in air forming a protective oxide coating. These materials are very heavy because both tungsten and molybdenum are high-density materials.

These materials, in particulate form, are packaged in sealed containers or drums to minimize contact with air and oxidation of the surface of the particles. The containers feel heavy for their size and are secured to a pallet or container to prevent movement.

**6.C.8. Maraging Steels, Usable in the Systems Specified in 1.A. or 19.A.1., Having All of the Following:**

A. **Having an Ultimate Tensile Strength, Measured at 20° C, Equal to or Greater Than:**
   1. **0.9 Gpa in the Solution Annealed Stage; or**
   2. **1.5 Gpa in the Precipitation Hardened Stage; and**

B. **Any Of The Following Forms:**
   1. **Sheet, Plate, or Tubing With a Wall or Plate Thickness Equal to or Less Than 5.0 mm; or**
   2. **Tubular Forms With a Wall Thickness Equal to or Less Than 50 mm and Having an Inner Diameter Equal to or Greater Than 270 mm.**

(ROK Doc: Item 57) Maraging Steel

Maraging steels are iron alloys: a. Generally characterised by high nickel, very low carbon content and use substitutional elements or precipitates to produce strengthening and age- hardening of the alloy; and b. Subjected to heat treatment cycles to facilitate the martensitic transformation process (solution annealed stage) and subsequently age hardened (precipitation hardened stage).

Maraging steel has a lustrous gray color when clean and freshly prepared. If the metal has been subjected to an aging treatment to improve strength, it may have a dark oxide layer on the surface. This dark layer may also indicate that the maraging steel has been subjected to a controlled degree of oxidation in order to improve corrosion resistance during service.

Maraging steel is often shipped in the low-strength, non-heat-treated condition so that it can be formed into the desired shape by the end user. It is bundled and shipped much like stainless steel, which it closely resembles. Sheets and plates are stacked and secured to a pallet. Tubes are bundled and secured to a pallet as well. Both may be covered with plastic sheet and/or crated to protect the materials from the shipping environment.

**6.C.9. Titanium-Stabilized Duplex Stainless Steel (Ti-Dss) Usable in the Systems Specified In 1.A. or 19.A.1. and Having All of the Following:**

**A. Having All of the Following Characteristics:**

1. **Containing 17.0 - 23.0 Weight Percent Chromium and 4.5 - 7.0 Weight Percent Nickel;**
2. **Having a Titanium Content of Greater Than 0.10 Weight Percent; and**
3. **A Ferritic-Austenitic Microstructure (Also Referred to as a Two-Phase Microstructure) of Which at Least 10% Is Austenite By Volume (According to Astm E-1181-87 or National Equivalents); and**

**B. Any of the Following Forms:**

1. **Ingots or Bars Having a Size of 100 mm or More in Each Dimension;**
2. **Sheets Having a Width of 600 mm or More and a Thickness of 3 mm or Less; or**
3. **Tubes Having an Outer Diameter of 600 mm or More and a Wall Thickness of 3 mm or Less.**

(ROK Doc: Item 59)
Duplex Stainless
Steel

Ti-DSS is virtually identical in appearance to other stainless steels. It has a very fine grain, which usually requires a magnifying glass or microscope to view.

Ti-DSS is generally bundled and shipped much like other stainless steels. Sheets and ingots or bars are often stacked and secured to a pallet. Tubes are usually bundled and secured to a pallet as well. Both may be covered with plastic sheet and/or crated to protect the materials from the shipping environment.

# ITEM 6: PRODUCTION OF STRUCTURAL COMPOSITES, PYROLYTIC DEPOSITION AND DENSIFICATION, AND STRUCTURAL MATERIALS

6.D. SOFTWARE S/2012/947 Category 1

### 6.D.1. "Software" Specially Designed or Modified for the "Use" of Equipment Specified in 6.B.1.

Typical composite and fiber production equipment software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs and documents can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network.

### 6.D.2. "Software" Specially Designed or Modified for the Equipment Specified in 6.B.3., 6.B.4., or 6.B.5.

Typical composite and fiber production equipment software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network.

# ITEM 6: PRODUCTION OF STRUCTURAL COMPOSITES, PYROLYTIC DEPOSITION AND DENSIFICATION, AND STRUCTURAL MATERIALS

6.E. TECHNOLOGY S/2012/947 Category 1

### 6.E.1. "Technology," in Accordance with the General Technology Note, for the "Development," "Production" or "Use" of Equipment, Materials, or "Software" Specified in 6.A., 6.B., 6.C., or 6.D.

In general, technical data can take the form of blueprints, plans, diagrams, models, formulae, engineering designs and specifications, and manuals and instructions written or recorded on other media or devices such as disk, tape and read-only memories. These data are usually provided in handbooks and graphs as part of either the autoclave or hydroclave manufacturer's documentation, or as a part of the resin manufacturer's recommendations.

The manufacturer's documentation refers to each of the subcomponents and compiles specifications and instruction manuals for each of them. These components include items such as solid-state controllers or computers for controlling and monitoring temperature and pressure during the cure operation.

The data accompanying the equipment and containing the cure information are typically placed in loose-leaf books or a collated set of instructions. Documentation has a report format and accompanies new equipment. Data supplied by manufacturers of resin or prepreg are on data sheets and accompany the raw resin or prepreg material.

### 6.E.2. "Technical Data" (Including Processing Conditions) and Procedures for the Regulation of Temperature, Pressures or Atmosphere in Autoclaves or Hydroclaves When Used for the Production of Composites or Partially Processed Composites, Usable for Equipment or Materials Specified in 6.A. or 6.C.

In general, technical data can take the form of blueprints, plans, diagrams, models, formulae, engineering designs and specifications, and manuals and instructions written or recorded on other media or devices such as disk, tape and read-only memories. These data are usually provided in handbooks and graphs as part of either the autoclave or hydroclave manufacturer's documentation, or as a part of the resin manufacturer's recommendations. The manufacturer's documentation refers to each of the subcomponents and compiles specifications and instruction manuals for each of them. These components include items such as solid-state controllers or computers for controlling and monitoring temperature and pressure during the cure operation.

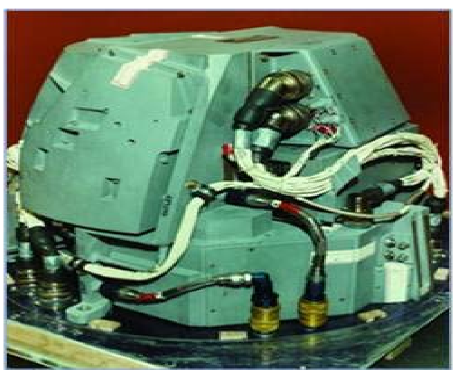
The data accompanying the equipment and containing the cure information are typically placed in loose-leaf books or a collated set of instructions. Documentation has a report format and accompanies new equipment. Data supplied by manufacturers of resin or prepreg (cloth-like material made of fibers and impregnated with resins) are on data sheets and accompany the raw resin or prepreg material.

**6.E.3. "Technology" for Producing Pyrolytically Derived Materials Formed on a Mould, Mandrel, or Other Substrate from Precursor Gases Which Decompose in the 1,300° C to 2,900° C Temperature Range at Pressures of 130 Pa (1 mm Hg) to 20 Kpa (150 mm Hg) Including "Technology" for the Composition of Precursor Gases, Flow-Rates, and Process Control Schedules and Parameters.**

# ITEM 9: INSTRUMENTATION, NAVIGATION AND DIRECTION FINDING

9.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**9.A.1. Integrated Flight Instrument Systems Which Include Gyrostabilisers or Automatic Pilots, Designed or Modified for Use in the Systems Specified in 1.A., or 19.A.1. or 19.A.2. and Specially Designed Components Therefor.**



**The main body of a cruise missile's integrated flight**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

**A selection of integrated navigation systems (INS) designed for UAV applications. From left: an autopilot and mission management system for UAVs and other military applications; a fully-integrated INS/GPS system; and a system which has integrated solid-state gyros, accelerometers, magnetometer and GPS receiver. (Rockwell Collins)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Systems designed for UAVs can be as small as 0.2 m x 0.2 m x 0.1m, and weigh as little as 1 kg (see Figure 2). Others, designed for cruise missiles or larger UAVs, can be as large as 0.5 m in length and weigh several kilograms. As with missile guidance systems controlled under 2.A.1.d., most integrated flight instrumentation systems controlled by 9.A.1. are enclosed in metallic (often aluminum) boxes, which often have removable access panels.

Equipment or “software” specified in 9.A. or 9.D. may be exported as part of a manned aircraft, satellite, land vehicle, marine/submarine vessel or geophysical survey equipment or in quantities appropriate for replacement parts for such applications.

Although integrated flight instrument systems are not as delicate and expensive as some of the more expensive ballistic missile guidance sets, their packaging is usually robust and includes desiccants and air-tight wrappers for protection against moisture. These systems are usually shipped in cushioned containers with labels indicating the need for careful handling.

**9.A.2. Gyro-Astro Compasses and Other Devices Which Derive Position or Orientation by Means of Automatically Tracking Celestial Bodies or Satellites, and Specially Designed Components Therefor.**

Although gyro-astro compasses vary considerably in design, the optical sensors, or telescopes, all have a visible optical lens, which may be protected by an automatic shutter or trap door. Many telescopes are gimbal-mounted (i.e., mounted inside one or more pivoting cages) and thus can be automatically pointed to locate an optical reference. A typical unit might measure less than half a meter and weigh less than 10 kg.

**A high resolution gyro-astro compass.**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Because gyro-astro compasses are delicate mechanisms, they are usually packed in robust shipping containers that prevent damage from moisture and mild shock. Shipping containers usually have warning labels indicating that they contain costly assemblies of sensitive optical, electrical, or mechanical equipment.

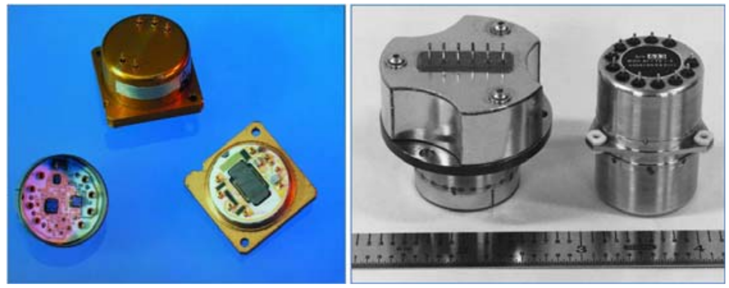
**9.A.3. Linear Accelerometers, Designed for Use in Inertial Navigation Systems or in Guidance Systems of All Types, Usable in the Systems Specified in 1.A., 19.A.1., or 19.A.2., Having All of the Following Characteristics, and Specially Designed Components Therefor:**

**A. “Scale Factor” “Repeatability” Less (Better) Than 1250 ppm; and**

**B. “Bias” “Repeatability” Less (Better) Than 1250 Micro G.**

**A pendulous integrating gyro**

Sourced: Missile Technology Control Regime Annex Handbook - 2010



**Left: An integrated circuit accelerometer. (Litton Sextant Avionique) Right: Two force-rebalance accelerometers that can be built with any of a wide range of performance capabilities. (Lockheed Martin Federal Systems)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

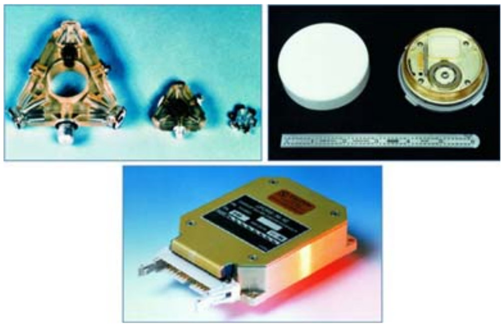
Item 9.A.3. does not control accelerometers specially designed and developed as Measurement While Drilling (MWD) sensors for use in downhole well service operations.

1. “Bias” is defined as the accelerometer output when no acceleration is applied. 2. “Scale factor” is defined as the ratio of change in output to a change in the input. 3. 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. 4. “Repeatability” is defined according to IEEE Standard 528-2001 as follows: “The closeness of agreement among repeated measurements of the same variable under the same operating conditions when changes in conditions or non-operating periods occur between measurements.”

They are usually cylindrical, metallic, and shiny from precision machining. The larger accelerometers used in ballistic missiles are several centimeters in length and can weigh up to several kilograms. Those used in UAVs, including cruise missiles, are smaller and lighter; they may measure only a few centimeters on a side and weigh less than a kilogram.

Because they are designed to be sensitive to acceleration, precision accelerometers are vulnerable to damage from relatively minor impact. They are usually protected from physical shock in small, high quality packages with thick, contour-fitted foam lining much like a package for a fine pocket watch. For shipping, one or more of these special boxes are packed in yet another box or other container with cushioned lining of some sort.

**9.A.4. All Types of Gyros Usable in the Systems Specified in 1.A., 19.A.1 or 19.A.2., With a Rated “Drift Rate” “Stability” of Less Than 0.5 Degrees (1 Sigma or Rms) Per Hour in a 1 G Environment, and Specially Designed Components Therefor.**



Top left: three exposed ring laser gyros without their associated electronics. (Honeywell) Top right: a fiber optic gyro with its top removed. (Honeywell) Bottom: a fiber optic rate sensing gyro. It is 2 cm x 6.5 cm x 8

Sourced: Missile Technology Control Regime Annex Handbook - 2010


A tactical grade inertial measurement unit is a high-performance fiber optic gyro-based motion sensor used in UAV guidance and navigation systems. (KVH)

Sourced: Missile Technology Control Regime Annex Handbook - 2010

1. “Drift rate” is defined as the component of gyro output that is functionally independent of input rotation and is expressed as an angular rate. (IEEE STD 528- 2001 paragraph 2.56)
2. “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. (This definition does not refer to dynamic or servo stability.) (IEEE STD 528-2001 paragraph 2.247)

Modern SDF gyros can be 5 cm to 8 cm in diameter and 8 cm to 12 cm long, and weigh up to 1 kg. DTGs are usually cylindrical with diameters of 4 cm to 6 cm and lengths of 4 cm to 8 cm, and generally weigh less than 1 kg. Older gyros can be somewhat larger, approximately twice the size of newer gyros and weigh several kilograms. Gyros used in UAVs, including cruise missiles, can be much smaller and lighter, perhaps weighing only tens of grams. Many gyros of MTCR concern have precision mounting surfaces for accurate alignment and high quality electrical connections. Because many designs exist, a gyro’s appearance can vary greatly. Spinning mass gyros are usually cylindrical, metallic, heavy for their size, and shiny from precision machining. Individual optical gyros are usually pad-like and mounted in a low profile, sealed box. A three-ring RLG unit will tend to be cubic and between 4 cm and 10 cm on a side. It may weigh between fractions of a kilogram to over a kilogram. Some single-axis designs resemble cylinders with diameters exceeding 20cm. Some FOG designs are only 2 cm to 4 cm in diameter, contain a fiber several hundred meters long, and weigh fractions of a kilogram.

Spinning mass gyros are vulnerable to damage from shock, but optical gyros are fairly rugged. Spinning mass gyros are packed in high quality, cushioned containers. Optical gyros do not need as much cushioning material in the package, but they are still likely to be shipped in high quality packages typical of expensive electronic instruments and sensors.

**9.A.5. Accelerometers or Gyros of Any Type, Designed for use in Inertial Navigation Systems or in Guidance Systems of All Types, Specified to Function at Acceleration Levels Greater Than 100 G, and Specially Designed Components Therefor.**

9.A.5. does not include accelerometers that are designed to measure vibration or shock.

Accelerometers may look identical to those covered in Item 9.A.3. Similarly, gyros specified to function at levels greater than 100 g may also be virtually identical in appearance to those covered in Item 9.A.4. They all are usually cylindrical or pad-like with precision mounting flanges and high quality electrical connectors.

Because of their rugged nature, these instruments do not need special handling. They are shipped as small hardware items.

**9.A.6. Inertial or Other Equipment Using Accelerometers Specified in 9.A.3. or 9.A.5. or Gyros Specified in 9.A.4. or 9.A.5., and Systems Incorporating Such Equipment, and Specially Designed Components Therefor.**

**An Inertial Measurement Unit (IMU) utilizes inertial fiber optic gyros (FOGs) and micro-machined accelerometers and is used in space stabilization, missile guidance, UAV guidance and flight control. (Northrop Grumman)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

They vary in size and weight depending on application. The IMU shown in Figure is 8 cm in height and just 8.5 cm in diameter, and weighs 750 g.

Because many accelerometers and gyroscopes are inherently delicate, they are packed in robust shipping containers with cushioning and insulation to prevent damage from shock and moisture. Containers may be wood, metal, or plastic with foam cushioning.

**9.A.7. "Integrated Navigation Systems," Designed or Modified for the Systems Specified in 1.A., 19.A.1. or 19.A.2. and Capable of Providing a Navigational Accuracy of 200 M CEP or Less.**

**An internal Inertial Measurement Unit (IMU) and GPS. (Northrop**

Sourced: Missile Technology Control

An "integrated navigation system" typically incorporates all of 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.

Integrated navigation system components (e.g., GPS receiver, inertial components, and integration hardware/processing) are typically mounted in rugged(ized) enclosures with several externally-visible connectors.

Integrated navigation systems would be shipped in metal or plastic crates or in padded cardboard boxes. External cabling and antennas may be included with a shipment depending on the intended platform.

**9.A.8. Three Axis Magnetic Heading Sensors Having All of the Following Characteristics, and Specially Designed Components Therefor:**

**A. Internal Tilt Compensation in Pitch (+/- 90 Degrees) and Having Roll (+/- 180 Degrees) Axes.**

**B. Capable of Providing Azimuthal Accuracy Better (Less) Than 0.5 Degrees Rms at Latitudes Of +/- 80 Degrees, Referenced to Local Magnetic Field; and**

**C. Designed or Modified to Be Integrated With Flight Control and Navigation Systems.**

Flight control and navigation systems in Item 9.A.8. include gyrostabilisers, automatic pilots and inertial navigation systems.

**This is a precision stand-alone magnetic heading sensor. (KVH)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Magnetic sensor components could be mounted as a triad directly on a printed circuit board within a navigation system or may be separated from other electronic components in their own non-ferrous enclosure. A separate enclosure allows the magnetic sensors to be mounted as far away as possible from ferrous materials in the host vehicle. Magnetic sensors are very small in size, with typical dimensions of around 2.5 cm x 2.5 cm x 15 cm. They are also very light, weighing around 15 g to 20 g.

Magnetic sensor components are shipped in small boxes or crates and are not themselves susceptible to shock damage. However, the tilt compensation components (e.g., accelerometers) could be affected by large shock events, thus requiring the entire system to be padded during shipping.

# ITEM 9: INSTRUMENTATION, NAVIGATION AND DIRECTION FINDING

9.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**9.B.1. "Production Equipment," and Other Test, Calibration and Alignment Equipment, Other Than That Described in 9.B.2., Designed or Modified to Be Used With Equipment Specified in 9.A.**

Equipment specified in 9.B.1. includes the following: a. For laser gyro equipment, the following equipment used to characterise mirrors, having the threshold accuracy shown or better: 1. Scatterometer (10 ppm); 2. Reflectometer (50 ppm); 3. Profilometer (5 Angstroms); b. For other inertial equipment: 1. Inertial Measurement Unit (IMU) Module Tester; 2. IMU Platform Tester; 3. IMU Stable Element Handling Fixture; 4. IMU Platform Balance Fixture; 5. Gyro Tuning Test Station; 6. Gyro Dynamic Balance Station; 7. Gyro Run-In/Motor Test Station; 8. Gyro Evacuation and Filling Station; 9. Centrifuge Fixture for Gyro Bearings; 10. Accelerometer Axis Align Station; 11. Accelerometer Test Station.

**9.B.2. Equipment as Follows:**

**A. Balancing Machines Having All the Following Characteristics:**
   **1. Not Capable of Balancing Rotors/Assemblies Having a Mass Greater Than 3 kg;**
   **2. Capable of Balancing Rotors/Assemblies at Speeds Greater Than 12,500 rpm;**
   **3. Capable of Correcting Unbalance in Two Planes or More; and**
   **4. Capable of Balancing to a Residual Specific Unbalance of 0.2 G mm per kg of Rotor Mass**

**B. Indicator Heads (Sometimes Known as Balancing Instrumentation) Designed or Modified for Use with Machines Specified in 9.B.2.A.**

**C. Motion Simulators/Rate Tables (Equipment Capable of Simulating Motion) Having All of the Following Characteristics:**
   **1. Two Axes or More; Capable of Balancing Rotors/Assemblies at Speeds Greater Than 12,500 rpm;**
   **2. Designed or Modified To Incorporate Sliprings or Integrated Non-Contact Devices Capableof Transferring Electrical Power, Signal Information, or Both; and**
   **3. Having Any of the Following Characteristics:**
      **A. For Any Single Axis Having All of the Following:**
         **1. Capable of Rates of 400 Degrees/S or More, or 30 Degrees/S or Less; and**
         **2. A Rate Resolution Equal To or Less Than 6 Degrees/S and an Accuracy Equal to or Less Than 0.6 Degrees/S;**
      **B. Having a Worst-Case Rate Stability Equal to or Better (Less) Than Plus or Minus 0.05% Averaged Over 10 Degrees or More; or**
      **C. A Positioning "Accuracy" Equal to or Less (Better) Than 5 Arc Second**

**D. Positioning Tables (Equipment Capable of Precise Rotary Positioning in Any Axes) Having the Following Characteristics:**
   **1. Two Axes or More; and**
   **2. A Positioning "Accuracy" Equal to or Less (Better) Than 5 Arc Second;**

**E. Centrifuges Capable of Imparting Accelerations Above 100 G and Designed or Modified to Incorporate Sliprings or Integrated Non-Contact Devices Capable of Transferring Electrical Power, Signal Information, or Both.**

9.B.2.a. does not control balancing machines designed or modified for dental or other medical equipment. 9.B.2.c. and 9.B.2.d. do not control rotary tables designed or modified for machine tools or for medical equipment. Item 9.B.2.e. applies whether or not sliprings or integrated non-contact devices are fitted at the time of export.

## ITEM 9: INSTRUMENTATION, NAVIGATION AND DIRECTION FINDING

9.C. MATERIALS S/2012/947 Category 1

No further information.

## ITEM 9: INSTRUMENTATION, NAVIGATION AND DIRECTION FINDING

9.D. SOFTWARE S/2012/947 Category 1

### 9.D.1. "Software" Specially Designed or Modified for the "Use" of Equipment Specified in 9.A. or 9.B.

Software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This software, including the documentation, can be transmitted over a computer network.

### 9.D.2. Integration "Software" for the Equipment Specified in 9.A.1.

Software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This software, including the documentation, can be transmitted over a computer network.

### 9.D.3. Integration "Software" Specially Designed for the Equipment Specified in 9.A.6.

Software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This software, including the documentation, can be transmitted over a computer network.

**9.D.4. Integration "Software," Designed or Modified for the "Integrated Navigation Systems" Specified in 9.A.7.**

Software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media including magnetic tape, floppy disks, removable hard disks, compact discs, and documents can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This software, including the documentation, can be transmitted over a computer network.

# ITEM 9: INSTRUMENTATION, NAVIGATION AND DIRECTION FINDING

9.E. TECHNOLOGY S/2012/947 Category 1

**9.E.1. "Technology," in Accordance With the General Technology Note, for the "Development," "Production" or "Use" of Equipment or "Software" Specified in 9.A., 9.B., or 9.D.**

No further information.

# ITEM 10: FLIGHT CONTROL

10.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**10.A.1. Hydraulic, Mechanical, Electro-Optical, or Electromechanical Flight Control Systems (Including Fly-By-Wire Systems) Designed or Modified for the Systems Specified in 1.A.**

Aerodynamic control surfaces and actuators are fairly robust pieces of equipment. Typical packaging includes wooden crates and cardboard or wooden boxes. They are securely attached to the shipping container to avoid movement and probably packed in foam shaped like the part. The sensors used in flight control systems are often more delicate and are normally individually wrapped and secured in a shock-resistant box or crate. They are often wrapped in a moisture-proof bag.

**10.A.2. Attitude Control Equipment Designed or Modified for the Systems Specified in 1.A.**

The two engines in the upper stage of the Safir(Utilizes Shahab-3) are assessed by Member States and experts consulted by the Panel to most closely resemble the vernier engines found on the R-27 submarine-launched ballistic missile, also known as the SS-N-6 (UN Doc. S/2013/331)

**Figure 1: An ectromechanical thrust vector control system, with linear actuator and associated electronics box, used on rockets, including space launch vehicles. (Moog, Inc)**

**Figure 2: A linear actuator used to position the pitch of rotor blades on a tilt rotor unmanned aerial vehicle and designed to operate under extreme environmental and endurance conditions. (Moog, Inc)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Vernier Thruster[1]
Image: en.wikipedia.org

The two engines in the upper stage of the Safir(Utilizes Shahab-3) are assessed by Member States and experts consulted by the Panel to most closely resemble the vernier engines found on the R-27 submarine-launched ballistic missile, also known as the SS-N-6 (UN Doc. S/2013/331).

Aerodynamic control surfaces and actuators are fairly robust pieces of equipment. Typical packaging includes wooden crates and cardboard or wooden boxes. They are securely attached to the shipping container to avoid movement and probably packed in foam shaped like the part. The sensors used in flight control systems are often more delicate and are normally individually wrapped and secured in a shock-resistant box or crate. They are often wrapped in a moisture-proof bag.

### 10.A.3. Flight Control Servo Valves Designed or Modified for the Systems in 10.A.1. or 10.A.2., and Designed or Modified to Operate in a Vibration Environment Greater Than 10 G Rms Between 20 Hz and 2 Khz.

Servo valves used in flight control systems may be constructed from stainless steel and have mounting swivels at either end. Hydraulic and electrical connections will be found on the side of the device.

Flight control servo valves are fairly robust pieces of equipment but they have sensitive position indicator mechanisms attached or built into the case. Typical packaging includes cardboard or wooden boxes. They are securely attached to the shipping container to avoid movement and probably packed in foam shaped like the part. They are often wrapped in a moisture-proof bag.

## ITEM 10: FLIGHT CONTROL

10.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**10.B.1. Test, Calibration, and Alignment Equipment Specially Designed for Equipment Specified in 10.A.**

Flight control test equipment looks like standard laboratory apparatus found in larger universities or aerospace industries, such as wind tunnels, electronic test benches, laser calibration devices, hydraulic or hydrodynamic test benches, etc. The equipment will consist of electronic test equipment, possibly computer controlled, electric and possibly hydraulic power supplies and rigid mechanical equipment to mount flight control actuators and control surfaces. Calibration points and alignment fixtures may be incorporated into these mountings.

New equipment or replacement spare parts are shipped separately in crates or protected on pallets for onsite assembly. They will be securely fastened to the crate to restrain motion and prevent damage. Smaller jigs may be individually crated or palletized for shipment. Test equipment is usually fragile and is so marked. It will include computer equipment, test stations, and corresponding support and interface components. There may be hydraulic pressurization systems and precision alignment fixtures included with the assemblies. Larger items may be palletized or crated in large wooden or metal crates, while smaller items will be in cardboard or wooden boxes.

# ITEM 10: FLIGHT CONTROL

10.C. MATERIALS S/2012/947 Category 1

No further information.

# ITEM 10: FLIGHT CONTROL

10.D. SOFTWARE S/2012/947 Category 1

**10.D.1. "Software" Specially Designed or Modified for the "Use" of Equipment Specified in 10.A. or 10.B.**

This software takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media – including magnetic tape, floppy disks, removable hard disks, compact discs, and documents – can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network.

# ITEM 10: FLIGHT CONTROL

10.E. TECHNOLOGY S/2012/947 Category 1

**10.E.1. Design "Technology" for Integration of Air Vehicle Fuselage, Propulsion System and Lifting Control Surfaces, Designed or Modified for the Systems Specified in 1.A. or 19.A.2., to Optimise Aerodynamic Performance Throughout the Flight Regime of an Unmanned Aerial Vehicle.**

Typically UAV design integration technology takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media – including magnetic tape, floppy disks, removable hard disks, compact disks, and documents – can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact disks, and documents containing design integration technology are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network. Other design integration technology consists of training and hands-on experience at foreign technology centers, for instance at instrumented wind tunnels.

**10.E.2. Design "Technology" for Integration of the Flight Control, Guidance, and Propulsion Data into a Flight Management System, Designed or Modified for the Systems Specified in 1.A. or 19.A.1., for Optimisation of Rocket System Trajectory.**

Typically, rocket design integration technology takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media – including magnetic tape, floppy disks, removable hard disks, compact disks, and documents – can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact disks, and documents containing design integration technology are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network. Other design integration technology consists of training and hands-on experience at foreign technology centers, for instance at instrumented wind tunnels.

**10.E.3. "Technology," in Accordance with the General Technology Note, for the "Development," "Production" or "Use" of Equipment or "Software" Specified in 10.A., 10.B., or 10.D.**

Typically, design integration technology takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media – including magnetic tape, floppy disks, removable hard disks, compact disks, and documents – can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact disks, and documents containing design integration technology are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network. Other design integration technology consists of training and hands-on experience at foreign technology centers, for instance at instrumented wind tunnels.

# ITEM 11: AVIONICS

11.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

### 11.A.1. Radar and Laser Radar Systems, Including Altimeters, Designed or Modified for Use in the Systems Specified in 1.A.

Laser radar systems embody specialised transmission, scanning, receiving and signal processing techniques for utilisation of lasers for echo ranging, direction finding and discrimination of targets by location, radial speed and body reflection characteristics. Equipment specified in 11.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).

Radar systems for missiles and UAVs (seekers or sensors) are normally designed as a single assembly consisting of an antenna subassembly located at one end of the system and the supporting power, control, and processing subassemblies located in one or more (separate but connected) housings. The antenna subassembly is normally a circular or oblong radiating and receiving, beam-forming element linked to both a power amplifier and waveguides, normally rectangular tubing that couples the signal from the amplifier to the radiating element. Antennas are either flat or parabolic and must be sized to fit within the missile diameter.

Equipment specified in 11.A. may be exported as part of a manned aircraft or satellite or in quantities appropriate for replacement parts for manned aircraft.

Although these systems are built to survive normal missile handling and storage, and severe flight environments, they must be carefully packaged to ensure that unusual stresses are not imposed by the shipping container and its environments. Because the antenna structure and drive systems are especially sensitive, they are well protected. The systems are sealed in an air-tight enclosure and shipped in cushioned containers. A wide range of outer containers may be used including metal drums, wooden boxes, and composite or metal cases.

**11.A.2. Passive Sensors for Determining Bearings to Specific Electromagnetic Sources (Direction Finding Equipment) or Terrain Characteristics, Designed or Modified for Use in the Systems Specified in 1.A.**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

**An infrared imaging sensor for a UAV (*top*) and its associated electronics. (LFK-GmbH)**

Direction finders consist of three assemblies: an antenna or antenna array, a receiver, and processing equipment. The antenna is a forward-looking parabolic dish, or a flat panel such as a phased array, usually mounted on a gimbaled assembly and sized for installation in the vehicle structure. The receiver is a small, low power assembly with connectors for power and signal outputs, and one or more coaxial antenna connectors. The size of the signal processing equipment ranges from a few centimeters to tens of centimeters on a side.

The antennas and optical elements may have special protective packaging because of their sensitivity to shock. These elements are sealed in airtight, moisture-proof enclosures and shipped in cushioned containers. In turn, these packages are shipped in a variety of containers, including metal drums, wooden boxes, or specialized composite or metal cases.

**11.A.3. Receiving Equipment for Global Navigation Satellite Systems (Gnss; e.g., Gps, Glonass or Galileo), Having Any of the Following Characteristics, and Specially Designed Components Therefor:**

**A. Designed or Modified for Use in Systems Specified in 1.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 Gnss Secure 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.**


**A Global Positioning System receiver/processor unit with its patch antenna. (Sextant Avionique)**

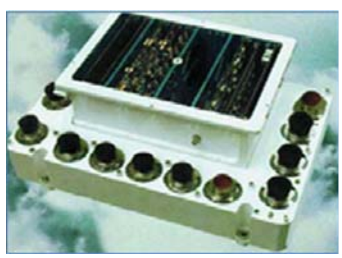
Sourced: Missile Technology Control Regime Annex Handbook - 2010

11.A.3.b.2. and 11.A.3.b.3. do not control equipment designed for commercial, civil or "Safety of Life" (e.g., data integrity, flight safety) GNSS services.

GNSS receivers are small, often just a few centimeters on a side, and quite light, often weighing less than 1 kg.

Packaging is typical for small, expensive electronics items. Military-grade items are very well packaged to protect against moisture from prolonged periods of storage.

**11.A.4. Electronic Assemblies and Components, Designed or Modified for Use in the Systems Specified In 1.A. or 19.A. and Specially Designed for Military Use and Operation at Temperatures in Excess of 125° C.**



**Digital signal processor with the lid removed. The size is 5 cm to 7.5 cm on each side.**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Electronic assemblies are usually small and lightweight, measuring a few centimeters in length on a side and a few grams in weight. The components of these assemblies resemble those used in a wide variety of commercial applications. However, electronic assemblies used in military applications are often hermetically sealed in metal or ceramic cases, not in the transparent plastic digital image processors (DIPs) used to contain commercial assemblies.

Electronic assemblies and components are usually shipped in plastic bags marked to designate an electrostatic sensitive device, cushioned in rubber foam or bubble wrap for shock protection, and shipped inside cardboard boxes or, for loads over 20 kg, wooden crates.

**11.A.5. Umbilical and interstage electrical connectors specially designed for systems specified in 1.A.1. or 19.A.1.**

Interstage connectors referred to in 11.A.5. also include electrical connectors installed between systems specified in 1.A.1. or 19.A.1. and their "payload."

# ITEM 11: AVIONICS

11.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

No further information.

# ITEM 11: AVIONICS

11.C. MATERIALS S/2012/947 Category 1

No further information.

# ITEM 11: AVIONICS

11.D. SOFTWARE S/2012/947 Category 1

**11.D.1. "Software" Specially Designed or Modified for the "Use" of Equipment Specified in 11.A.1., 11.A.2., or 11.A.4.**

Typically radar system software, software used with passive sensors and flight software suitable for 1.A. systems take the form of computer programs stored on printed, magnetic, optical, or other media. Any common media—including magnetic tape, floppy disks, removable hard disks, compact discs, and documents—can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network.

**11.D.2. "Software" Specially Designed for the "Use" of Equipment Specified in 11.A.3.**

Typically GNSS software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media – including magnetic tape, floppy disks, removable hard disks, compact discs, and documents – can contain this software and data. GPS receivers of MTCR concern cannot always be visually distinguished from uncontrolled GPS receivers because the altitude and velocity algorithms are implemented in firmware or software.

Magnetic tape, floppy disks, removable hard disks, compact discs and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network.

# ITEM 11: AVIONICS

11.E. TECHNOLOGY S/2012/947 Category 1

**11.E.1. Design "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 Determination of Hardening Criteria for the Above.**

No further information.

**11.E.2. "Technology," In Accordance With the General Technology Note, for the "Development," "Production" or "Use" of Equipment or "Software" Specified in 11.A. or 11.D.**

No further information.

# ITEM 12: LAUNCH SUPPORT

12.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**12.A.1. Apparatus and Devices, Designed or Modified for the Handling, Control, Activation and Launching of the Systems Specified in 1.A., 19.A.1., or 19.A.2.**

**Minimal launch pad with a gantry and connections to a complete rocket system. (MTCR Equipment, Software**

Sourced: Missile Technology Control Regime Annex

**A silo liner being lifted into place for installation into a missile silo at a launch complex under**

Sourced: Missile Technology Control Regime Annex

### 12.A.2. Vehicles Designed or Modified for the Transport, Handling, Control, Activation and Launching of the Systems Specified in 1.A.

UN Document S/2013/337
KN-08 missile on 8-axle transporter erector launcher and WS51200 vehicles as advertised by CASIC

Sourced: Restricted strategic commodities list for DPRK, issued June 2013 by Republic of Korea, Ministry of Unification, Strategic Materials Management Service

**Left: A pneumatic UAV launcher. Right: Command-and-control vehicles suitable for launching missiles from fixed or mobile locations. (MTCR Equipment, Software and Technology Annex Handbook, Third Edition (May 2005))**

**Eight axle and four axle TELs carrying intercontinental ballistic missiles (ICBMs; foreground) and intermediate range ballistic missiles (IRBMs). (Via Chinese Internet)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

China later furnished the UN Panel of Experts with a copy of the end user certificate provided by the Democratic People's Republic of Korea buyer (see annex XII, sect. A). Dated 5 November 2010, it stated that the "Democratic People's Republic of Korea Forestry Ministry Rim Mok General Trading Company, Limited" certified that "the six units of the off-road trucks (WS51200) which are imported from Wuhan Sanjiang Import and Export Company, Limited (China), according to the contract (contract No. IME10S054) are the vehicles for transporting the timbers in the Democratic People's Republic of Korea." Both Wuhan Sanjiang Import and Export Company and Wanshan are subsidiaries of the China Sanjiang Space Group. (UN Document S/2013/337).

The distinguishing feature of TELs designed for ballistic missiles is the presence of an erection mechanism capable of lifting the missile to a vertical position. The vehicle may be tracked, but most are large vehicles about the size of a tractor-trailer or lorry, with 3 to 8 axles and rubber tires.

The launch rails and erection mechanisms used on TELs or MELs are generally integrated into the vehicle or trailer chassis. As a result, these devices are placed in their normal stowed position on the mobile vehicle or trailer when packaged for shipment from the production facility. The vehicles are driven, towed, or shipped by rail to the user facility. Other vehicles will be packaged similarly to other military or commercial vehicles.

**12.A.3. Gravity Meters (Gravimeters), Gravity Gradiometers, and Specially Designed Components Therefor, Designed or Modified for Airborne or Marine Use, and Having a Static or Operational Accuracy Of 7 X 10-6 $m/S^2$ (0.7 Milligal) or Better, with a Time to Steady-State Registration of Two Minutes or Less, Usable for Systems Specified in 1.A.**

**This automated gravity meter is one of the most precise, rugged and lightweight gravity meters. Under normal conditions, it can be leveled for mGal readings within 30 seconds, and has a drift rate of less than 0.5 mGals per month when mature. (ZLS Corporation)**

Systems fully integrated into a single case may be as small as 25 cm x 32 cm x 32 cm and weigh as little as 6 kg (with battery). Systems with separate cases may be as large as a cubic meter and weigh 350 kg; these large systems are modular and may be packaged in more than one container for shipping. Electronic and mechanical components are enclosed in either hard plastic or metal cases. Some systems have the instrument and control panel contained in the same case; other systems have the instruments separated from the control panels. The cases typically have visible electronic or mechanical control panels, pads, rotating control knobs, toggle- and push-switches, and connections for external electronic and computer cables.

Because the systems are very sensitive and expensive, they are packaged and shipped in rigid containers, which include formed plastic, plastic popcorn, plastic bubble wrap, or other materials designed to protect them from shock. The shipping containers usually have warning labels such as “fragile,” “handle with care,” or ‘sensitive instruments.”

**12.A.4. Telemetry and Telecontrol Equipment, Including Ground Equipment, Designed or Modified for Systems Specified in 1.A., 19.A.1. or 19.A.2.**

**A Large telemetry antenna system designed for UAVs and flight test centers. (Chelton Antennas)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

1. 12.A.4. does not control equipment designed or modified for manned aircraft or satellites. 2. 12.A.4. does not control ground based equipment designed or modified for terrestrial or marine applications. 3. 12.A.4. does not control equipment designed for commercial, civil or “Safety of Life” (e.g., data integrity, flight safety) GNSS services.

Because of the sensitivity of the electronics, telemetry equipment is usually shipped in cushioned cardboard or wooden containers. Some containers may have labels indicating the need for careful handling. Usually the equipment is sealed in plastic to protect the electronics from moisture and electrostatic discharges. Large assemblies of equipment such as integrated telecontrol stations will be disassembled and shipped in separate containers.

**12.A.5. Precision Tracking Systems, Usable for Systems Specified in 1.A., 19.A.1. or 19.A.2. as Follows:**

**A. Tracking Systems Which Use a Code Translator Installed on the Rocket or Unmanned Aerial Vehicle in Conjunction with Either Surface or Airborne References or Navigation Satellite Systems to Provide Real-Time Measurements of Inflight Position and Velocity;**

**B. Range Instrumentation Radars Including Associated Optical/Infrared Trackers with All of the Following Capabilities:**

**3. Angular Resolution Better Than 1.5 mrad;**

**4. Range of 30 km or Greater With a Range Resolution Better Than 10 m rms; and**

**5. Velocity Resolution Better Than 3 m/s.**

**A mobile phased-array missile tracking radar. (MTCR Equipment, Software and Technology Annex**

**A mobile laser missile tracking system. (Contraves)**

**An electro-optical laser tracking system. (BAE Systems)**

Sourced: Missile Technology Control Regime Annex Handbook -

Precision tracking systems and range instrumentation radars look like ground-based portions of telemetering and telecontrol equipment. They include familiar dish-type radars as well as phased-array radars, which are characterized by their flat (rather than dish) surface. Also used are optical devices that look like telescopes, large robotic binoculars and laser tracking systems that resemble optical instruments.

Because of its sensitivity to shock, the electronic equipment is usually shipped in cushioned containers. Some may have labels indicating the need for careful handling. This equipment is usually sealed in plastic to protect it from moisture and electrostatic discharge. The larger radars, optical trackers, and laser trackers are shipped disassembled in wooden crates and assembled onsite and all optics are protected with environmental covers.

**12.A.6. Thermal Batteries Designed or Modified for the Systems Specified in 1.A., 19.A.1. or 19.A.2.**

**A selection of thermal batteries designed for a range of military applications. (HBL Power Systems)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Item 12.A.6. does not control thermal batteries specially designed for rocket systems or unmanned aerial vehicles that are not capable of a "range" equal to or greater than 300 km. Thermal batteries are single use batteries that contain a solid non-conducting inorganic salt as the electrolyte. These batteries incorporate a pyrolytic material that, when ignited, melts the electrolyte and activates the battery.

Thermal Batteries are manufactured in vacuum sealed steel housings. They are relatively small in size, ranging from around 3.5 cm to 17.5 cm in breadth and 6 cm to 22 cm in height. Weight ranges from around 200 g to 1.2 kg.

Thermal Batteries are shipped in metal or plastic crates or in padded cardboard boxes.

## ITEM 12: LAUNCH SUPPORT

12.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

No further information.

## ITEM 12: LAUNCH SUPPORT

12.C. MATERIALS S/2012/947 Category 1

No further information.

## ITEM 12: LAUNCH SUPPORT

12.D. SOFTWARE S/2012/947 Category 1

### 12.D.1. "Software" Specially Designed or Modified for the "Use" of Equipment Specified in 12.A.1.

Typically, missile ground support and checkout software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media—including magnetic tape, floppy disks, removable hard disks, compact discs, and documents—can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network.

### 12.D.2. "Software" Which Processes Post-Flight, Recorded Data, Enabling Determination of Vehicle Position Throughout Its Flight Path, Specially Designed or Modified for Systems Specified in 1.A., 19.A.1. or 19.A.2.

Typically, software that processes missile post-flight, recorded information that is used to determine the test flight trajectory takes the form of a computer program stored on printed, magnetic, optical or other media. Any common media— including magnetic tape, floppy disks, removable hard disks, compact discs and documents—can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network.

### 12.D.3. "Software" Specially Designed or Modified for the "Use" of Equipment Specified in 12.A.4. or 12.A.5., Usable for Systems Specified in 1.A., 19.A.1., or 19.A.2.

Typically, software that collects and processes missile telemetry takes the form of a computer program stored on printed magnetic, optical or other media. Any common media—including magnetic tape, floppy disks, removable hard disks, compact discs, and documents— can contain this software and data.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing this software are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This technology, including the documentation, can be transmitted over a computer network.

## ITEM 12: LAUNCH SUPPORT

12.E. TECHNOLOGY S/2012/947 Category 1

### 12.E.1. "Technology," in Accordance with the General Technology Note, for the "Development," "Production" or "Use" of Equipment or "Software" Specified in 12.A. or 12.D.

No further information.

# ITEM 13: COMPUTERS

13.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**13.A.1. Analogue Computers, Digital Computers or Digital Differential Analysers, Designed or Modified for Use in the Systems Specified in 1.A., Having Any of the Following Characteristics:**
**A. Rated for Continuous Operation at Temperatures from Below -45° C to Above +55° C; or**
**B. Designed as Ruggedised or "Radiation Hardened."**

**A mission computer for multiple platforms. Its compact size makes it ideal for the confined space on some UAVs. (Curtiss Wright Embedded Computing Controls)**

**Another mission computer for multiple platforms, this one is designed for use in harsh aerospace and military applications. (Curtiss Wright Embedded Computing Controls)**

**A radiation-hardened electronics assembly with liquid cooling. (The Charles Stark Draper Laboratory, Inc.)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Computers configured for missiles and UAVs are usually housed in metal enclosures with integral heat sinks to dissipate heat generated by high operating speeds. They are also compact in size and designed to fit into space-constrained environments. A distinguishing characteristic (although not unique to military use) is hermetically sealed metal and ceramic components as opposed to more common plastic components found in commercial electronics.

Electronic computer assemblies and parts typically weigh less than 25 kg. They are packaged in plastic bags, placed inside cardboard boxes, and packed in rubber foam or bubble wrap shock protection; box labels typically indicate the contents as electrostatic sensitive devices. Larger units integrated into a larger system and over 25 kg may be packed in metal or wooden boxes.

# ITEM 13: COMPUTERS

13.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

No further information.

## ITEM 13: COMPUTERS

13.C. MATERIALS S/2012/947 Category 1

No further information.

## ITEM 13: COMPUTERS

13.D. SOFTWARE S/2012/947 Category 1

No further information.

## ITEM 13: COMPUTERS

13.E. TECHNOLOGY S/2012/947 Category 1

**13.E.1. "Technology," in Accordance with the General Technology Note, for the "Development," "Production" or "Use" of Equipment Specified in 13.A.**

No further information.

## ITEM 14: ANALOGUE TO DIGITAL CONVERTERS

14.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**14.A.1. Analogue-to-Digital Converters, Usable in the Systems Specified in 1.A., Having Any of the Following Characteristics:**

**A. Designed to Meet Military Specifications for Ruggedised Equipment; or**

**B. Designed or Modified for Military Use and Being Any of the Following Types:**

  **1. Analogue-to-Digital Converter "Microcircuits," Which Are "Radiation-Hardened" or Have All of the Following Characteristics:**

    **A. Having a Quantisation Corresponding to 8 Bits or More When Coded in the Binary System;**

    **B. Rated for Operation in the Temperature Range From Below -54° C to Above +125° C; and**

    **C. Hermetically Sealed; or**

  **2. Electrical Input Type Analogue-to-Digital Converter Printed Circuit Boards or Modules, Having All of the Following Characteristics:**

A. **Having a Quantisation Corresponding to 8 Bits or More When Coded in the Binary System;**
B. **Rated for Operation in the Temperature Range from Below -45° C to Above +55° C; and**
C. **Incorporating "Microcircuits" Specified in 14.A.1.B.1.**


**An analog-to-digital converter used primarily in radar signal analysis. (Datel)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Military ADC components are hermetically sealed metal packages in order to ensure operation in adverse environment extremes and to dissipate the heat associated with processing data at high data rates from sensors. Aluminum is the primary metal used for ADC board frames, structures, and heat sinks. ADCs can range from a few centimeters to about 0.3 m or more on a side and weigh from 100 g up to 25 kg. Their package density approaches one-third the density of aluminum.

ADC printed circuit board assemblies and modules weigh less than 25 kg. They are encased in plastic bags that are marked to indicate electrostatic sensitive devices, and they are packed in rubber foam or bubble wrap for shock protection inside cardboard boxes.

## ITEM 14: ANALOGUE TO DIGITAL CONVERTERS

14.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

No further information.

## ITEM 14: ANALOGUE TO DIGITAL CONVERTERS

14.C. MATERIALS S/2012/947 Category 1

No further information.

## ITEM 14: ANALOGUE TO DIGITAL CONVERTERS

14.D. SOFTWARE S/2012/947 Category 1

No further information.

# ITEM 14: ANALOGUE TO DIGITAL CONVERTERS

14.E. TECHNOLOGY S/2012/947 Category 1

**14.E.1. "Technology," in accordance with the General Technology Note, for the "development," "production" or "use" of equipment specified in 14.A.**

No further information.

# ITEM 15: TEST FACILITIES AND EQUIPMENT

15.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

No further information.

# ITEM 15: TEST FACILITIES AND EQUIPMENT

15.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**15.B.1. Vibration test equipment, usable for the systems specified in 1.A., 19.A.1. or 19.A.2. or the subsystems specified in 2.A. or 20.A., and components therefor, as follows:**

**a. Vibration test systems employing feedback or closed loop techniques and incorporating a digital controller, capable of vibrating a system at an acceleration equal to or greater than 10 g rms between 20 Hz and 2 kHz while imparting forces equal to or greater than 50 kN, measured "bare table";**

**b. Digital controllers, combined with specially designed vibration test "software," with a "real-time control bandwidth" greater than 5 kHz and designed for use with vibration test systems specified in 15.B.1.a.;**

"Real-time control bandwidth" is defined as the maximum rate at which a controller can execute complete cycles of sampling, processing data and transmitting control signals.

**c. Vibration thrusters (shaker units), with or without associated amplifiers, capable of imparting a force equal to or greater than 50 kN, measured "bare table," and usable in vibration test systems specified in 15.B.1.a.;**

**d. Test piece support structures and electronic units designed to combine multiple shaker units into a into a complete shaker system capable of providing an effective combined force equal to or greater than 50 kN, measured "bare table," and usable in vibration test systems specified in 15.B.1.a.**

**An example of a thruster with slip table. (Kingdom Pty Ltd)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Vibration test systems incorporating a digital controller are those systems, the functions of which are, partly or entirely, automatically controlled by stored and digitally coded electrical signals.

**15.B.2. "Aerodynamic Test Facilities" for Speeds of Mach 0.9 or More, Usable for the Systems Specified in 1.A. or 19.A. or the Subsystems Specified in 2.A. or 20.A.**

Item 15.B.2 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.

1. "Aerodynamic test facilities" includes wind tunnels and shock tunnels for the study of airflow over objects.

2. "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.

**15.B.3. Test benches/stands, usable for the systems specified in 1.A., 19.A.1. or 19.A.2. or the subsystems specified in 2.A. or 20.A., which have the capacity to handle solid or liquid propellant rockets, motors, or engines having a thrust greater than 68 kN, or which are capable of simultaneously measuring the three axial thrust components.**

No further information.

**15.B.4. Environmental chambers as follows, usable for the systems specified in 1.A. or 19.A. or the subsystems specified in 2.A. or 20.A.:**

**a. Environmental chambers capable of simulating all the following flight conditions:**

  **1. Having any of the following:**

    **a. Altitude equal to or greater than 15 km; or**

**b. Temperature range from below –50° C to above 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 imparting forces equal to or greater than 5 kN;**

**A controlled environmental chamber with vibration capability. (RMS Dynamic Test Systems)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

1. Item 15.B.4.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 Item 15.B.4.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 this Item.

Environmental pressure chambers are rugged, usually metal, airtight, cylindrical chambers with bulged or hemispherical ends to withstand the external pressure of one atmosphere (plus safety margin). They often have thick glass or acrylic viewing ports. An access panel or door at one end is used to insert and remove test items. They are often linked to large vacuum pumps that evacuate the chamber. Their size is a function of the items to be tested; thus, they can range from less than a meter to tens of meters on a side. They are usually supported by numerous buildings housing pumps, power, data collection, and operations.

**15.B.5. Accelerators Capable of Delivering Electromagnetic Radiation Produced by Bremsstrahlung From Accelerated Electrons of 2 Mev or Greater, and Equipment Containing Those Accelerators, Usable for the Systems Specified in 1.A., 19.A.1. or 19.A.2. or the Subsystems Specified in 2.A. or 20.A.**

**A 2.3MeV flash X-ray unit used for inspecting solid rocket motors. (MTCR Equipment, Software and Technology Annex Handbook, Third Edition (May 2005))**

Sourced: Missile Technology Control Regime Annex

15.B.5. does not control equipment specially designed for medical purposes. In Item 15.B. "bare table" means a flat table, or surface, with no fixture or fittings.

These X-ray machines consist of five major parts: the accelerator, the X-ray head, the RF amplifiers or modulators, a control console, and a water pump cabinet.

Linear accelerators are packaged for shipment in crates or boxes. They may appear as three separate cabinets. The X-ray head and modulator normally come from the same vendor. The cooling system and the control system can be purchased separately. The packaging uses foam, Styrofoam, or other shock-attenuating fill to protect the modulator from excessive vibration and shock. The equipment may be labeled with X-ray caution labels, RF field signs, and possibly labels indicating highvoltage. The system may be heavier than lower-energy systems because of the amount of lead shielding, if shipped with shielding installed, required to shield personnel from penetrating X-rays. The electrostatic accelerators are much larger. The high-voltage supply and the acceleration tube are shipped together inside the pressure vessel. Because of its weight, the pressure vessel is most likely shipped in a crate made for fork-lift handling. The unit is not likely to be shipped in operational condition and usually has additional packing material inside the pressure vessel to support the high-voltage supply and acceleration column.

# ITEM 15: TEST FACILITIES AND EQUIPMENT

15.C. MATERIALS S/2012/947 Category 1

No further information.

# ITEM 15: TEST FACILITIES AND EQUIPMENT

15.D. SOFTWARE S/2012/947 Category 1

**15.D.1. "Software" specially designed or modified for the "use" of equipment specified in 15.B. usable for testing systems specified in 1.A., 19.A.1., or 19.A.2. or subsystems specified in 2.A. or 20.A.**

No further information.

# ITEM 15: TEST FACILITIES AND EQUIPMENT

15.E. TECHNOLOGY S/2012/947 Category 1

**15.E.1. "Technology," in accordance with the General Technology Note, for the "development," "production" or "use" of equipment or "software" specified in 15.B. or 15.D.**

No further information.

# ITEM 16: MODELLING-SIMULATION AND DESIGN INTEGRATION

16.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**16.A.1. Specially designed hybrid (combined analogue/digital) computers for modeling, simulation, or design integration of systems specified in 1.A. or the subsystems specified in 2.A.**

Software for missile design is physically indistinguishable from commercial software. It is contained on the same computer disks or CD-ROMs, etc. Missile analog/hybrid computers are custom electronics generally smaller than a breadbox. Flight motion computers are cabinets with commercial standard electronics racks. Missile software and specialized flight dynamics models can also be loaded on a pure digital, real-time computer (flight emulator). Real-time models can be used to replace the test article hardware in the loop.

Custom electronics like analog/hybrid computers may be packaged in a variety of ways, including trunk containers used for shipping sensitive instruments and computer monitors. Flight motion computers are generally shipped like other electronic equipment. Other flight simulator hardware, including flight motion tables, may be packed in wooden crates for shipment. Models and real-time software look like any other software product and are packaged in cardboard boxes, possibly in shrink wrap (if commercial/new) or on unmarked standard transfer media, such as floppy disks, CD-ROMs, or ¼ inch magnetic tape cartridges.

# ITEM 16: MODELLING-SIMULATION AND DESIGN INTEGRATION

16.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

No further information.

## ITEM 16: MODELLING-SIMULATION AND DESIGN INTEGRATION

16.C. MATERIALS S/2012/947 Category 1

No further information.

## ITEM 16: MODELING-SIMULATION AND DESIGN INTEGRATION

16.D. SOFTWARE S/2012/947 Category 1

**16.D.1. "Software" specially designed for modeling, simulation, or design integration of the systems specified in 1.A. or the subsystems specified in 2.A or 20.A.**

Software for missile design is physically indistinguishable from commercial software. It is contained on the same type of computer disks or CD-ROMs, etc. used for other software. Alternatively, missile software and specialized flight dynamics models can be loaded on a pure digital, real-time computer (flight emulator). Real-time models can be used to replace the test article hardware in the loop.

Models and real-time software look like any other software product and are packaged in cardboard boxes, possibly in shrink wrap (if commercial/new) or on unmarked standard transfer media, such as floppy disks, CD-ROMs, or ¼ inch magnetic tape cartridges.

## ITEM 16: MODELLING-SIMULATION AND DESIGN INTEGRATION

16.E. TECHNOLOGY S/2012/947 Category 1

**16.E.1. "Technology," in accordance with the General Technology Note, for the "development," "production" or "use" of equipment or "software" specified in 16.A. or 16.D.**

No further information.

## ITEM 17: STEALTH

17.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**17.A.1. Devices for Reduced Observables Such as Radar Reflectivity, Ultraviolet/Infrared Signatures and Acoustic Signatures (i.e., Stealth Technology), for Applications Usable for the Systems Specified in 1.A. or 19.A. or the Subsystems Specified in 2.A. or 20.A.**

**Absorbing Honeycomb has a variety of applications in defense and aerospace, including stealth. (Supracor)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

**Four radar absorbing material foams, clockwise from upper left: low-dielectric foam (epoxy); lightweight lossy foam (urethane); sprayable lightweight foam (urethane); and thermoplastic foam (polytherimide). (MTCR Equipment, Software and Technology Annex Handbook, Third Edition (May 2005))**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Typical devices that result in reduced-observable treatments include, but are not limited to, the following categories: There are two kinds of conductive fillers: conductive fibers, which look like very light whiskers 2 mm to 6 mm long, are made of carbon, metals, or conductive material coated glass fibers; and conductive-material coated particles, which may look like colored sand.

Small cell foams: both open and closed, are painted, or loaded, with absorbing inks and paints. These foams resemble flexible foam rubber sheets or air conditioning filters.

Resistive Cards (R-Cards) consist of a sheet of fiber paper or very thin plastic covered with a continuous coat of a conductive ink, paint, or extremely thin metallic film.

Loaded ceramic spray tiles are sprayed-on and fired ceramic coatings heavily loaded with electrically conductive fillers or ferromagnetic particles. They are likely to range from dark gray to black in color. Depending on the specific filler and surface-sealing glaze used, they may range from smooth to abrasive in surface texture. Sprayed-on coatings may range from a few millimeters to tens of centimeters in thickness.

Absorbing honeycomb is a lightweight composite with open cells normally 3 mm to 12 mm in diameter and 25 mm to 150 mm maximum thickness.

Absorbing fibers vary from 2 mm to 6 mm in length and are usually packaged in plastic bags, vials, or jars. Their weight depends on the materials used. Fibers shipped before being chopped to their functional length may be in the form of conventional spools of textile fibers or in bundles 1 m to 2 m in length and 2 cm to 10 cm in diameter.

Foams come in sheets usually no larger than 1 m x 1 m, ranging from 6 mm to 200 mm in thickness, and weighing less than 40 g per square meter. They are packaged in cardboard boxes. R-Cards are packaged in an envelope or box with a nonabrasive paper sheet between each card. Larger quantities may be shipped in rolls from 0.2 m to 1 m in length and 15 cm in diameter, inside desiccated tubes, or in cardboard boxes. Loaded ceramic spay tiles are usually bubble wrapped and packaged in cardboard boxes. Absorbing honeycomb is shipped in cardboard boxes

# ITEM 17: STEALTH

17.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**17.B.1. Systems, specially designed for radar cross section measurement, usable for the systems specified in 1.A., 19.A.1., or 19.A.2. or the subsystems specified in 2.A.**

Transmission/reflection tunnel RCS measurement systems look like large, sheet metal, air vent ducting. They have two matching metal feed horns with coaxial cabling or waveguides leading to the radar source and detector measurement electronics. They are controlled by a computer that looks like any PC with a keyboard and a monitor.

Radar ranges are seldom shipped as one piece; rather, they are assembled onsite from many components. There are no unique packaging requirements for this equipment beyond those of the industry standard for rack-mounted electronics and commercial computer components. Some of the components (such as the Cassegrain reflectors) can be fairly large and require special crates. Styrofoam target supports are delicate and must be packaged to prevent denting.

# ITEM 17: STEALTH

17.C. MATERIALS S/2012/947 Category 1

**17.C.1. Materials for reduced observables such as radar reflectivity, ultraviolet/infrared signatures and acoustic signatures (i.e., stealth technology), for applications usable for the systems specified in 1.A. or 19.A. or the subsystems specified in 2.A.**

1. 17.C.1. includes structural materials and coatings (including paints), specially designed for reduced or tailored reflectivity or emissivity in the microwave, infrared or ultraviolet spectra. 2. 17.C.1. does not control coatings (including paints) when specially used for thermal control of satellites.

Typical materials for reduced-observable treatments include, but are not limited to, the following categories:

- Sprays include conductive inks or paints
- Magnetic Radar Absorbing Material (commonly known as Mag RAM)
- Transparent Radar Absorbent Material (T-RAM) looks like sheet polycarbonate
- Infrared (IR) Treatments usually consist of paints and coatings.

Spray paints and inks are generally shipped in standard-size cans. The cans may be in boxes containing desiccants, or the pigments and binders may be shipped separately. Pigments are shipped in jars, plastic bags or cans, and the binders are shipped in cans or drums. Most are highly toxic or caustic materials until applied and cured. Mag RAM may be shipped in sheets, uncured slurries and finished parts, or in raw material form (particles, binder and polymerization-activator all shipped separately).The particles would most likely be shipped in a very fine powder or short fiber form but possibly also immersed in a hydrophobic fluid to prevent rusting. It may be shipped in sheets up to a few meters in length and width. Sheet thickness may range from less than a millimeter up to tens of centimeters. It may be shipped several layers deep on flat pallets or as a rolled sheet inside a cardboard tube. If shipped as formed parts, it may be in rectangular cardboard or wooden boxes as large as 0.1 m x 0.1 m x 2.0 m or as small as 20 cm x 20 cm x 20 cm.

# ITEM 17: STEALTH

17.D. SOFTWARE S/2012/947 Category 1

**17.D.1. "Software" specially designed for reduced observables such as radar reflectivity, ultraviolet/infrared signatures and acoustic signatures (i.e., stealth technology), for applications usable for the systems specified in 1.A. or 19.A. or the subsystems specified in 2.A.**

17.D.1. includes "software" specially designed for analysis of signature reduction.

# ITEM 17: STEALTH

17.E. TECHNOLOGY S/2012/947 Category 1

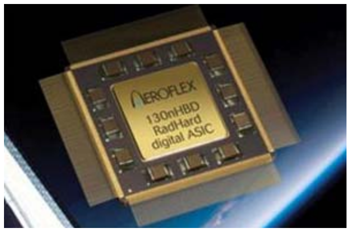
**17.E.1. "Technology," in accordance with the General Technology Note, for the "development," "production" or "use" of equipment, materials or "software" specified in 17.A., 17.B., 17.C., or 17.D.**

17.E.1. includes databases specially designed for analysis of signature reduction.

# ITEM 18: NUCLEAR EFFECTS PROTECTION

18.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**18.A.1. "Radiation Hardened" "microcircuits" usable in protecting rocket systems and unmanned aerial vehicles against nuclear effects (e.g., Electromagnetic Pulse (EMP), X-rays, combined blast and thermal effects), and usable for the systems specified in 1.A.**




**A radiation hardened application specific integrated circuit (ASIC) designed for high reliability and**

Sourced: Missile Technology Control Regime Annex

Hardened electronic component devices and their assemblies are typically mounted in hermetically sealed metal or ceramic packages with surface-mounted devices common in high density assemblies. They look like commercial devices, but they may have part numbers identifying them as hardened.

Electronic assemblies and components are typically shipped in plastic bags marked to designate an electrostatic sensitive device. They are cushioned in rubber foam or bubble wrap for shock protection and packed inside cardboard boxes.

**18.A.2. "Detectors" specially designed or modified to protect rocket systems and unmanned aerial vehicles against nuclear effects (e.g., Electromagnetic Pulse (EMP), X-rays, combined blast, and thermal effects), and usable for the systems specified in 1.A.**

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.

Electronic assemblies and components are typically shipped in plastic bags marked to designate an electrostatic sensitive device. They are cushioned in rubber foam or bubble wrap for shock protection and packed inside cardboard boxes.

**18.A.3. Radomes designed to withstand a combined thermal shock greater than 4.184 x 106 J/m$^2$ accompanied by a peak over pressure of greater than 50 kPa, usable in protecting rocket systems and unmanned aerial vehicles against nuclear effects (e.g., Electromagnetic Pulse (EMP), X-rays, combined blast and thermal effects), and usable for the systems specified in 1.A.**

**Left: a selection of aerodynamic radomes (Northrop Grumman). Right: radomes similar to those that might be used to protect RV seekers on reentry. (American Technology & Research Industries)**



Sourced: Missile Technology Control Regime Annex

Radomes used to protect nose-mounted sensors in RVs are conical in shape, as shown in Figure 4. They range in size depending on the size of the RV to which they are attached, and can be as small as 30 cm, and as large as 2 m or more in diameter and length. The materials are basically dielectrics in solid laminates or sandwiched foam formed as a single, one-piece molded radome. A thin wall, dielectric space frame (DSF) radome, usually 0.1 cm or less in thickness, may be used for small antennas. A solid laminate-wall DSF radome typically is 0.25 cm in thickness.

Radomes are shipped in wooden crates that have contour braces within them to support their thin wall structure. Radomes have closure frames mounted on their aft flanges to maintain structural rigidity in transit and are wrapped in polyethylene bags. Crates can use either formed wooden bulkheads for contour bracing or polyurethane, foamed in place, to support the radome.

## ITEM 18: NUCLEAR EFFECTS PROTECTION

18.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

No further information.

## ITEM 18: NUCLEAR EFFECTS PROTECTION

18.C. MATERIALS S/2012/947 Category 1

No further information.

## ITEM 18: NUCLEAR EFFECTS PROTECTION

18.D. SOFTWARE S/2012/947 Category 1

No further information.

## ITEM 18: NUCLEAR EFFECTS PROTECTION

18.E. TECHNOLOGY S/2012/947 Category 1

**18.E.1. “Technology,” in accordance with the General Technology Note, for the “development,” “production” or “use” of equipment specified in 18.A.**

No further information.

# ITEM 19: OTHER COMPLETE DELIVERY SYSTEMS

19.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**19.A.1. Complete rocket systems (including ballistic missile systems, space launch vehicles, and sounding rockets), not specified in 1.A.1., capable of a "range" equal to or greater than 300 km.**


**A large Category II sounding rocket, capable of delivering a 250 kg payload to a range of 400 km. The rocket's solid propellant motor, with steel casing, is surrounded by four honeycomb tail fins with titanium alloy leading edges. (JAXA)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Complete rocket systems in this category are very similar in appearance to those in 1.A.1., but on a smaller scale. They are large, long, narrow cylinders which, when assembled, typically have dimensions of at least 5 m in length, 0.5 m in diameter, and at least a 1,500 kg weight with a full load of propellant.

The major components of rocket systems are usually shipped in crates or sealed metal containers to an assembly facility near the launch location, where they are assembled, tested for their operational readiness. Exceptions include mobile ballistic missiles, which can be fully assembled and stored in a horizontal position in a mobile transporter-erector-launcher (TEL) and moved to the launch point when required.

**19.A.2. Complete unmanned aerial vehicle systems (including cruise missile systems, target drones and reconnaissance drones), not specified in 1.A.2., capable of a "range" equal to or greater than 300 km.**

A medium-range endurance UAV. Despite its small size, this elastic catapult-launched UAV is capable of carrying a 1 kg payload (IR and digital cameras) to a range of 400 km. (Aerovision Vehiculos Aereos, SL)

Left: A selection of composite rocket motor cases designed to support a range

Purpose built UAVs typically exhibit a conical shape, sometimes with a bulbous area near the front end or nose of the fuselage. Complete UAV systems controlled under this item also may include manned aircraft that are modified to fly autonomously as optionally piloted vehicles. Such systems also usually retain a cockpit, which is empty or filled with electronic equipment or payload during flight. Larger UAVs covered by 19.A.2. have several features in common with those in 1.A.2., which might include mid-mounted wings with large spans, cylindrical fuselages with pronounced bulges or domes above the nose, rear mounted engines, V or inverted V tails, and fully retractable landing gear. Cruise missiles in this category are very similar in appearance to those in 1.A.2.

Category II UAVs, including cruise missiles, are manufactured in components or sections at different locations and by different manufacturers, and assembled at a military site or a civilian production facility. UAVs described by this Item may be packaged as complete units, or they may be separated at break points and packaged using the same procedures and materials as the UAVs described in 1.A.2.

**19.A.3. Complete unmanned aerial vehicle systems, not specified in 1.A.2. or 19.A.2., having all of the following:**

**a. Having any of the following:**

**1. An autonomous flight control and navigation capability; or**

**2. Capability of controlled flight out of the direct vision range involving a human operator; and**

A rotary-wing UAV designed with chemical tanks and spray bars for agricultural purposes. (Yamaha)

Sourced: Missile Technology Control Regime Annex Handbook - 2010

The majority of known systems for conducting autonomous aerial spraying are helicopter-based.

**b. Having any of the following:**

1. **Incorporating an aerosol dispensing system/mechanism with a capacity greater than 20 litres; or**
2. **Designed or modified to incorporate an aerosol dispensing system/mechanism with a capacity greater than 20 litres.**

**A Modular Aerial Spray System, used for pesticide application, can use a setting called ultra-low volume and specialized spray boom nozzles such as those shown here to spread one half to an ounce of chemical over an acre. (U.S. Air Force)**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

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.

# ITEM 19: OTHER COMPLETE DELIVERY SYSTEMS

19.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**19.B.1. "Production facilities" specially designed for the systems specified in 19.A.1 or 19.A.2.**

No further information.

## ITEM 19: OTHER COMPLETE DELIVERY SYSTEMS

19.C. MATERIALS S/2012/947 Category 1

No further information.

## ITEM 19: OTHER COMPLETE DELIVERY SYSTEMS

19.D. SOFTWARE S/2012/947 Category 1

**19.D.1. "Software" which coordinates the function of more than one subsystem, specially designed or modified for "use" in the systems specified in 19.A.1. or 19.A.2.**

The software described in this Item has the same appearance as that described in Item 1.D.2.

Magnetic tape, floppy disks, removable hard disks, compact discs, and documents containing software that controls more than one subsystem and that is specially designed or modified for use in systems specified in 19.A. are indistinguishable from any other storage media. Only labeling and accompanying documentation can indicate its use unless the software is run on the appropriate computer. This software and documentation can be transmitted over a computer network.

## ITEM 19: OTHER COMPLETE DELIVERY SYSTEMS

19.E. TECHNOLOGY S/2012/947 Category 1

**19.E.1. "Technology," in accordance with the General Technology Note, for the "development," "production" or "use" of equipment specified in 19.A. 1. or 19.A.2**

No further information.

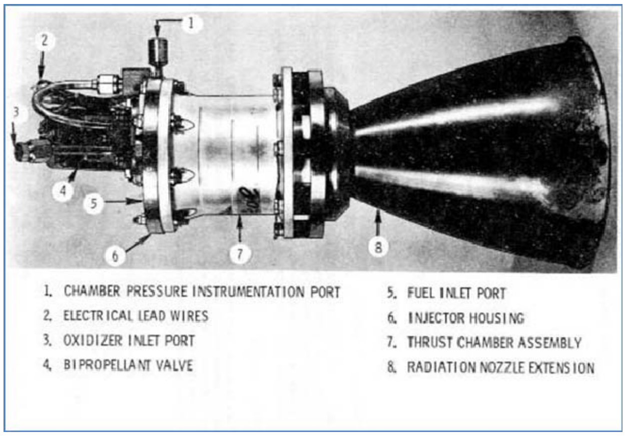
## ITEM 20: OTHER COMPLETE SUBSYSTEMS

20.A. EQUIPMENT, ASSEMBLIES, AND COMPONENTS S/2012/947 Category 1

**20.A.1. Complete subsystems as follows:**

**a. Individual rocket stages, not specified in 2.A.1., usable in systems specified in 19.A.;**

**b. Solid propellant rocket motors, hybrid rocket motors, or liquid propellant rocket engines, not specified in 2.A.1., usable in systems specified in 19.A., having a total impulse capacity equal to or greater than 8.41 x 105 Ns, but less than 1.1 x 106 Ns.**




**A reaction control engine**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

**A stack of solid propellant rocket motors controlled under Category II. Motors on the left of that photo are large**

Sourced: Missile Technology Control Regime Annex Handbook - 2010

Like their larger counterparts controlled by 2.A.1., Individual rocket stages controlled by 20.A.1. are cylinders ranging from 3 m to 10 m in length and 0.2 m to 2 m in diameter. These cylinders are manufactured from robust sheet steel, composite materials (fibers or resins), or a combination of both. Solid propellant rocket motors are cylindrical tubes with oval or circular domes at both ends for attachment of the igniter and nozzle, respectively. Nozzles are usually attached prior to shipment. The size and dimensions of these motors depends on their purpose.

Rocket stages are shipped in purpose-built steel or wooden containers or crates. Solid rocket motors are usually shipped in steel or aluminum containers or wooden crates.

# ITEM 20: OTHER COMPLETE SUBSYSTEMS

20.B. TEST AND PRODUCTION EQUIPMENT S/2012/947 Category 1

**20.B.1. "Production facilities" specially designed for the subsystems specified in 20.A.**

Item 20.B.1. production facilities and equipment for the complete stages and solid propellant rocket motors and liquid propellant rocket engines are similar to those described in Item 2.B.1. The facilities and equipment described in this Item may be indistinguishable from those designed to produce larger rocket stages or liquid propellant rocket engines. However, they may be smaller in size. Production facilities and equipment for individual rocket stages and motors controlled by 20.A.1. are similar to those discussed in 2.A.1., and in most cases will be indistinguishable from those for larger items.

**20.B.2. "Production equipment" specially designed for the subsystems specified in 20.A.**

Item 20.B.2. “production equipment” is similar to the equipment for the complete stages and solid propellant rocket motors and liquid propellant rocket engines described in Item 2.B.2. The equipment described in this Item may be indistinguishable from that designed to produce larger rocket stages or liquid propellant rocket engines. However, it may be smaller in size.

# ITEM 20: OTHER COMPLETE SUBSYSTEMS

20.C. MATERIALS S/2012/947 Category 1

No further information.

# ITEM 20: OTHER COMPLETE SUBSYSTEMS

20.D. SOFTWARE S/2012/947 Category 1

**20.D.1. “Software” specially designed or modified for the systems specified in 20.B.1.**

The “software” described in this Item has the same nature and purpose as that described in Item 2.D.1.

Typically this software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media—including magnetic tape, floppy disks, removable hard disks, compact discs, and documents—can contain this software and data.

**20.D.2. “Software,” not specified in 2.D.2., specially designed or modified for the “use” of rocket motors or engines specified in 20.A.1.b.**

The “software” described in this Item has the same nature and purpose as that described in Item 2.D.2.

Typically this software takes the form of a computer program stored on printed, magnetic, optical, or other media. Any common media – including magnetic tape, floppy disks, removable hard disks, compact discs, and documents – can contain this software and data.

# ITEM 20: OTHER COMPLETE SUBSYSTEMS

20.E. TECHNOLOGY S/2012/947 Category 1

**20.E.1. “Technology,” in accordance with the General Technology Note, for the “development,” “production” or “use” of equipment or “software” specified in 20.A., 20.B., or 20.D.**

No further information.