ITEM 11
Avionics

Avionics

Avionics equipment, "technology" and components as follows; designed or modified for use in the systems in Item 1, and specially designed software therefor:
(a) Radar and laser radar systems, including altimeters;

Notes to Item 11:

(1) Item 11 equipment may be exported as part of a manned aircraft or satellite or in quantities appropriate for replacement parts for manned aircraft.
(2) Examples of equipment included in this Item:
  (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);
(3) In subitem (a), laser radar systems embody specialized transmission, scanning, receiving and signal processing techniques for utilization of lasers for echo ranging, direction finding and discrimination of targets by location, radial speed and body reflection characteristics.

Produced by companies in

- Australia
- China
- France
- Germany
- India
- Israel
- Italy
- Japan
- Norway
- Russia
- South Africa
- South Korea
- Sweden
- Taiwan
- United Kingdom
- United States

Nature and Purpose: Radars, laser radars (LADARs), and infrared (IR) laser radars (LIDARs) are sophisticated active sensor systems that can be used for reconnaissance, target homing, or guidance in unmanned air vehicles (UAVs), especially cruise missiles. Radar scene-matching correlators have been used in UAVs and ballistic missiles. Radar and laser altimeters are somewhat less sophisticated devices used for navigation and terrain avoidance in cruise missiles and weapon fusing in cruise and ballistic missiles. In recent years, significant technological improvements have occurred in transmitters, receivers, antennas, and electronic processing.

Method of Operation: Radar, LADAR, and LIDAR systems operate similarly. They emit a pulse of electromagnetic energy and detect the energy reflected to them from the terrain or target below. Distance is computed as a product of half the elapsed time between signal transmission and reception, and the speed of light. The direction of the target or terrain is given by the angle between the two pulses. The image of the terrain or target thereby created can be compared with stored images, and missile course can be altered as needed.

Radar and laser altimeters operate similarly, but measure only the distance from the missile to the ground. Such altimeters make precise measurements of distance above ground to help low flying missiles avoid terrain and, when compared with elevation maps, can be used as navigation aids. Radar altimeters may also be used in altitude fusing of ballistic missiles.

Doppler navigation systems operate like radar altimeters, but compare the frequencies, not the transit time, of the transmitted beams and the returned energy. The change in frequency is a result of missile movement relative to the ground and can be directly converted to missile velocity. Multiple antennas can measure missile velocity in any direction if they receive enough returned energy. This velocity information can be used to correct for accumulated guidance errors.

Typical Missile-Related Uses: These systems are used in cruise missiles as sensors for target discrimination, homing, and warhead fusing. They are also used as navigation aids for keeping the missile on a prescribed flight path and at certain flight altitudes. Such sensors can also be used for terminal guidance or fusing of ballistic missiles.

Other Uses: Radar and Doppler navigation systems are used on military and commercial aircraft and ships for navigation, weather detection, and collision avoidance. Radar altimeters are commonly used for numerous purposes such as determining height above the terrain on many types of aircraft. LIDARs have been used for atmospheric measurements, oceanographic studies, and smokestack emissions studies.

Appearance (as manufactured): 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. The antennas are fixed in electronically scanning systems or gimbaled in mechanical scanning systems. The antenna-mounting features and support structure are strong enough to maintain stability and accuracy in the presence of substantial accelerations caused by launch, turbulence, and maneuvering. The shape and weight of the support structure and ancillary equipment housings vary greatly from system to system, but may have some features peculiar to missile applications. For example, to help reduce missile cross-sectional area and improve cooling, the equipment boxes may have one or more cylindrical or conical surfaces and may have mounting features to ensure good contact with the missile skin or provide for coolant flow rather than external fins for air-cooling.

Radar altimeters are generally much smaller than radar seekers or other sensors with fixed, surface-mounted transmitter and receiver antennas. These antennas, which must point toward the ground, are usually flat, rectangular, or circular plates with a mounting surface conforming to the exterior of the missile. The power- and signal-processing requirements are significantly less than those for radar seeker systems. The transmitter and receiver are normally enclosed within one box connected to the antenna by a coaxial cable. This subassembly usually has a volume of less than $0.05m^3$ and does not require external cooling. A typical Doppler system consisting of a receiver/transmitter/antenna assembly typically occupies $0.007m^3$, weighs less than 5 kg, and requires about 12 watts of power.

LADAR and LIDAR systems differ from radar systems in that they use the much shorter visible-light and IR wavelengths respectively. They are easily distinguished by the external appearance of an optical lens or window. Systems operating at longer IR wavelengths have an optical port that may appear to be metallic. Like radar antennas, the optical unit of the system is fixed or movable, and it may be mounted separately. Construction is heavy, with rugged mounts. In general, all of these systems have mounting surfaces that are unpainted but coated with a conductive anti-corrosion film. The electrical grounding of all avionics chassis is vital to survival in hostile electromagnetic environments.

Appearance (as packaged): 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.

Produced by companies in

- Australia
- China
- France
- Germany
- India
- Israel
- Italy
- Japan
- Norway
- Russia
- South Africa
- Sweden
- Taiwan
- United Kingdom
- United States

(b) Passive sensors for determining bearings to specific electromagnetic sources (direction finding equipment) or terrain characteristics;

Nature and Purpose: Direction finding systems provide a vehicle with bearing information (angular orientation) to known sources of electromagnetic radiation emanating from ground-based transmitters. Terrain and target characteristics may be determined by imaging systems, typically a visible or infrared (IR) camera. These systems are passive because they receive but do not transmit energy; thus, missiles using them are much less likely to be detected. Both systems are used for UAV guidance and as payload sensors, and in some cases have been used for terminal guidance of ballistic missiles.

Method of Operation: Direction finding equipment uses passive sensors to receive electromagnetic radiation from ground transmitters at various known points. For example, comparing the relative transit times of the signals from two or more sites allows the computer on the missile to determine its location and heading. This information is used by the integrated flight instrumentation system to follow the preprogrammed flight plan. An antiradiation homing seeker guides the missile to the target by processing the received radar energy from a single emitter.

Imaging sensors may use terrain characteristics to navigate. The optical assembly consists of one or more lenses of fixed or variable focal length, an image intensifier, and a photosensitive array for converting the scene into a digital map. This assembly operates in the visible or IR wavelengths. Visible light systems using a high-intensity flash illuminator at night thus become semi-active sensors. The sensors collect images of ground scenes at predetermined points along a preprogrammed flight path. The images are digitized and compared to stored scenes of the same locations. Differences between the two scenes are converted into a position error used to correct vehicle heading. Alternatively, image sensors can be used in man-in-the-loop guidance where the image of the target area is relayed to a person who actually flies the vehicle. The operator can either guide the UAV to impact or lock the missile on the target after which the missile homes autonomously to impact.

Typical Missile-Related Uses: Inertial guidance systems updated by imaging systems can be used to guide cruise missiles with extraordinary accuracy or for terminal guidance of ballistic missiles. Direction finding equipment can be used to guide UAVs and for ballistic missile terminal guidance.

Other Uses: Interferometer direction finding systems are used in aircraft, ships, and land vehicles. Image sensors are used in many tactical military systems for ordnance delivery, particularly from aircraft. Imaging sensor technology (sensors and algorithms) is also used extensively in robotics and photography. Imaging systems built for cruise missiles, however, usually have no commercial applications.

Appearance (as manufactured): 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 missile structure. The receiver is a small, low power assembly with connectors for power and signal outputs, and one or more coaxial antenna connectors. The signal processing equipment can be integral to other

Figure 11-1: An infrared imaging sensor for an unmanned air vehicle (top) and its associated electronics.

Photo Credit: LFK-Lenkflugkorpersysteme GmbH

Figure 11-2: A gyro stabilized IR camera with its window.

electronics or resident in its own electronics box. The appearance of such signal processing electronics varies greatly and may reflect manufacturer preferences rather than the functional purpose of the equipment. The size of the signal processing equipment ranges from a few centimeters to tens of centimeters on a side.

Imaging sensors consist of a lens and a visible or IR sensor, or camera. They are used with an electronic assembly consisting of a power supply and control and processing electronics, as shown in Figure 11-1. Another IR camera is shown in Figure 11-2. Visible-light sensors are recognizable by the optical lens or window. The optical port of IR light sensors may appear metallic. The flash unit has a large optical window covering a reflector and glass tube.

Imaging sensors may be either fixed or movable, and they may be mounted separately from the rest of the terrain-mapping equipment. The optics mounting features and supporting structure are robust in order to maintain stability and accuracy in the presence of large accelerations during launch, turbulence, and maneuvering. The surface of the unit close to the lens may be shaped to fit the contour of the bottom of the missile because the lens must look at the ground during flight.

Appearance (as packaged): The antennas and optical elements may have special protective packaging because of their sensitivity to shock. These elements are sealed in an 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.

Produced by companies in

- China
- France
- Germany
- Israel
- Japan
- Russia
- South Africa
- United Kingdom
- United States

(c) Global Positioning System (GPS) or similar satellite receivers;
  (1) Capable of providing navigation information under the following operational conditions;
    (i) At speeds in excess of 515 m/sec (1,000 nautical miles/ hour); and
    (ii) At altitudes in excess of 18 km (60,000 feet); or
  (2) Designed or modified for use with unmanned air vehicles covered by Item 1.

Nature and Purpose: Global Positioning System (GPS) receivers are small electronic units with power and antenna connections used to provide vehicle position and velocity information. The Global Navigation Satellite System (GLONASS) is a satellite system similar to GPS.

Method of Operation: GPS receivers detect radio signals transmitted from GPS satellites orbiting the earth in precisely known orbits. These radio signals identify the satellite and contain an accurate time reference. The receiver determines its position and velocity by measuring the signal delay among four or more satellites simultaneously and calculating the results on the basis of their locations and other information contained in the signal. GLONASS operates in much the same way as GPS. Combined GPS/GLONASS receivers may also be used.

Typical Missile-Related Uses: Military-grade and commercially available GPS and GLONASS receivers are used in integrated flight instrumentation systems to provide very accurate navigation information to UAVs, including cruise missiles. Specially designed receivers can also be used in ballistic missiles to supplement or update the guidance set and increase missile accuracy.

Photo Credit: Sextant Avionique

Figure 11-3: Global positioning system receiver/processor unit with its patch antenna.

Other Uses: GPS and GLONASS receivers described in Item 11(c) (1) have capabilities required primarily by rocket systems and have few other uses. GPS and GLONASS receivers described in Item 11(c) (2) can be used in airplanes and helicopters.

Appearance (as manufactured): GPS and GLONASS receivers are small, often just a few centimeters on a side, and quite light, often less than a kilogram in weight as shown in Figure 11-3. GPS receivers of MTCR concern cannot always be visually distinguished from uncontrolled GPS receivers because the altitude and velocity limits are implemented in firmware within the microcircuits. Determination of whether a given GPS receiver is MTCR-controlled is best made on the basis of the receiver model, serial number, and associated documentation. GPS receivers are also available as part of a complete guidance package, as shown in Figure 11-4.

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

(d) Electronic assemblies and components specially designed for military use and operation at temperatures in excess of 125 degrees C.

Photo Credit: Litton Guidance & Control Systems

Figure 11-4: A complete guidance package based upon Global Positioning System receivers.

Nature and Purpose: Generally speaking, missile designers try to fit very capable systems into small packages. "Very capable" means that a lot of power is required (such as in a long-range radar or an accurate guidance set), and "small packages" means that power densities are high. If the electronics can be designed to withstand high temperatures, then weight from materials otherwise required for cooling can be avoided. Electronic assemblies and components used in such situations result from extensive design and testing efforts to ensure reliability when used in high-temperature environments. The purpose of rugged, heat-tolerant electronic items is to ensure weapons system performance and reliability while minimizing weight and space.

Method of Operation: These military electronic assemblies and components typically run on batteries and operate much like other electronics. However, a greater margin against failure is designed into them, and their improved reliability has been confirmed by temperature-cycle testing and accelerated-age testing.

Typical Missile-Related Uses: Heat-tolerant electronics are used in guidance computers, inertial navigation systems, and reentry vehicles in ballistic missiles. They are also useful in radars, computers, and seeker systems on UAVs.

Other Uses: Electronic assemblies and components have virtually unlimited uses in all types of military aircraft and other military systems. The same types of assemblies with similar specifications are often used in commercial aircraft and marine vessels, although there may be no confirmation of the claimed reliability through documented exhaustive testing as in the case of military assemblies.

Appearance (as manufactured): 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

Figure 11-5: Digital signal processor with the lid removed. The size is 5 to 7.5 cm on each side.

Photo Credit: AAI Corp.

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 DIPs used to contain commercial assemblies. Exceptions are high-performance processors such as the quad digital signal processor (DSP) in a multi-chip module package, as shown in Figure 11-5. This DSP includes stacked, high-density memory chips for exceptional speed and memory capacity. The presence of such high cost devices suggests a possible military use; however, some assemblies may look more conventional such as that shown in Figure 11-6.

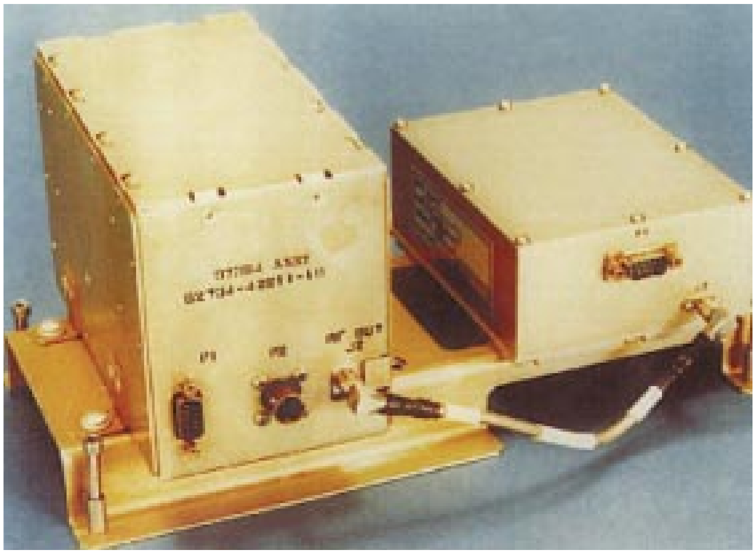

Figure 11-6: Unmanned air vehicle electronics boxes.

Electronic assemblies for military use are often designed to dissipate heat. In some assemblies, the integral heat sinks are supplemented by water cooling. Cable interfaces feature rugged circular connectors or small bolt-on connectors with shielded cables. The electronics are typically mounted within an outer radio frequency (RF) shield (Faraday cage), which may be hermetically sealed or vented to the ambient pressure. Pressurized vessels are sometimes used for missiles and UAVs which must operate at high altitude in order to help conduct heat to the case and the heat sink mounting. Cases are made mainly of aluminum, with exposed metal surfaces painted or treated with corrosion-resistant materials such as nickel plating.

Appearance (as packaged): 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.

Produced by companies in

- China
- France
- Japan
- Russia
- United Kingdom
- United States

(e) Design technology for protection of avionics and electrical subsystems against electromagnetic pulse (EMP) and electromagnetic interference (EMI) hazards from external sources, as follows:
  (1) Design technology for shielding systems;
  (2) Design technology for the configuration of hardened electrical circuits and subsystems;
  (3) Determination of hardening criteria for the above.

Nature and Purpose: Electromagnetic pulse (EMP) and electromagnetic interference (EMI) technology is used to enhance the survival of systems in environments that have intense manmade RF noise, particularly RF noise caused by detonating nuclear weapons. The technology uses at least three approaches, often simultaneously: it configures sensitive circuits in order to minimize interference; it encloses curcuits in conductive boxes; and it protects input/output (I/O) wires by surge suppression devices, commonly just inside the conductive box.

Although the technology used to protect circuits from EMP and EMI is common and unremarkable, determining requirements and implementing them are difficult and sophisticated problems. Circuit topologies, suppression device usage, weapon effects prediction models, and criteria generation can be investigated by interactive computer programs, which input weapon and system parameters and output threat environments such as fields and current levels.

Method of Operation: EMP and EMI protection is generally passive. RF enclosures dissipate RF energy as electrical eddy currents in the conductive outer surface. Care is taken with lids and doors to ensure that fields cannot leak into an enclosure; metal gaskets and screens are typically used to seal such openings. I/O suppression devices simply short electric fields to ground or provide high impedance (i.e., electrical opposition) by using RF chokes and filters. However, some suppression devices like zener diodes, transorbs, spark gaps, and metal oxide varistors change their impedance at certain voltage or current levels.

Typical Missile-Related Uses: EMP and EMI design technology is used in ballistic missiles to protect the guidance set and electronic equipment in the reentry vehicle from the EMP and EMI effects from nearby nuclear detonations. It is also used to protect pyrotechnic devices such as stage-separation systems from premature ignition. This technology can be used in UAVs, but they generally need only be protected against lower levels of EMP and EMI encountered at considerable distance from nuclear blasts or other sources of interference.

Other Uses: EMP and EMI design technology is used in satellites, some military aircraft, and some weapons systems. Similar EMI technology is used in the design of some commercial electronic systems such as shortwave radios and stereo equipment to reduce or prevent interference from other electrical devices. Surge suppression devices for lightning strikes on power supplies and cords is another example of EMP/EMI protection.

Appearance (as manufactured): Such design technology can take the form of technical assistance, including training and consulting services. Technology can also 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.

Photo Credit: Sabritec

Figure 11-7: Some electromagnetic interference suppression devices.

Some design technology is conveyed by the equipment itself. Assemblies are RF-shielded in metal enclosures, usually aluminum. For very lightweight applications, durable composite or rugged plastic boxes are used with a thin coating of metal for RF shielding. The coating is usually aluminum, often on the inside surface of the box. Exposed metal surfaces are often painted or treated with corrosion-resistant materials such as nickel plating. Some EMI suppression devices are shown in Figure 11-7. An EMI/EMP electronics module is shown in Figure 11-8. The electronics are protected by the aluminum perimeter that serves as a RF Faraday cage when hermetically sealed by the mating modules and cover. The aluminum surface beneath the circuit board serves as an RF partition of the internal modules. The bolt pattern for the cover is spaced every few centimeters to prevent gaps in the closure and to maintain even pressure on an RF gasket that may be soft metal, metal-filled gasket, metal spring, or wire mesh. EMI/EMP electronics may take on almost any shape to fit space constraints.

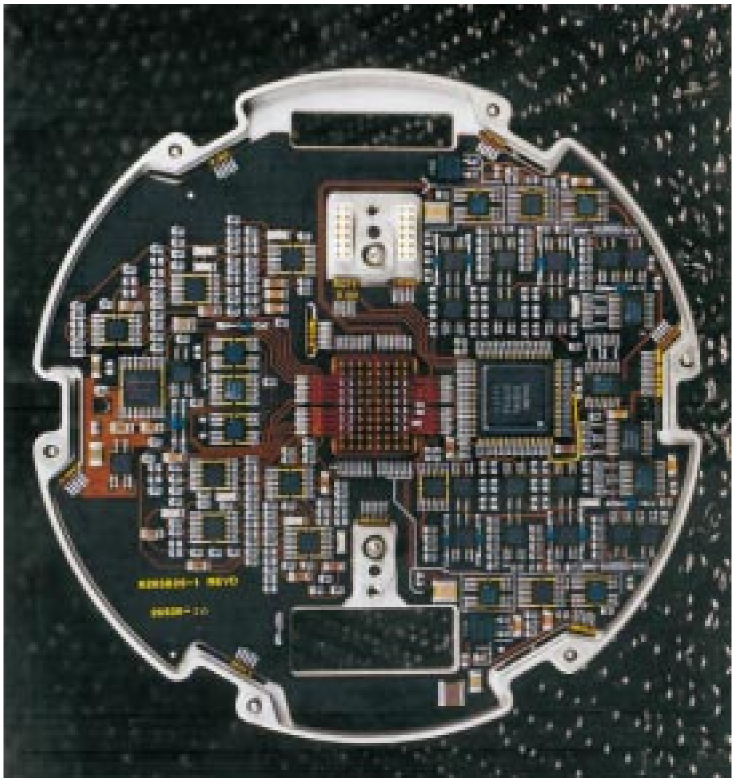

Photo Credit: The Charles Stark Draper Laboratory, Inc.

Figure 11-8: Electromagnetic interference/ electromagnetic pulse electronics module.

Appearance (as packaged): Technology in forms such as reports, data, and criteria generating programs may be packaged in oversized business envelopes or in ordinary computer electronic media mass distribution packages. Electronic EMP/EMI assemblies are typically shipped with rubber foam or bubble wrap shock protection in cardboard or, if they weigh more than 20 kg, in wooden boxes. They are occasionally shipped in electrostatic-sensitive device (ESD) marked plastic bags even though they are not ESD-sensitive.