ITEM 12
Launch Support

Launch Support

Launch support equipment, facilities and software for the systems in Item 1, as follows:

(a) Apparatus and devices designed or modified for the handling, control, activation and launching of the systems in Item 1;

Produced by companies in

- Australia
- China
- France
- Germany
- India
- Iran
- Israel
- Italy
- Japan
- Netherlands
- North Korea
- Russia
- South Korea
- Sweden
- Taiwan
- United Kingdom
- United States

Nature and Purpose: The launch support equipment covered in Item 12(a) includes all apparatus and devices designed or modified for performing the function specified (handling, control, etc.) of Item 1 systems. Items that provide these functions for mobile or fixed systems are controlled. Examples of such apparatus and devices include, but are not limited to, launch pad facilities, gantries, block houses, underground launch silos, handling equipment, systems test and check-out equipment, and command-and-control equipment. Some of this equipment is relatively simple such as concrete launch pads. Other items are complex such as the sophisticated pad and gantry type launch facilities used for modern space launch vehicles (SLVs). The determining factor is whether the item is designed or modified for an Item 1 system.

Method of Operation: The key operations and equipment used in launching a ballistic missile depend on the nature of the approach. In most approaches, the missile is delivered to the site by a truck, a train, or, at a launch pad, a dolly. The missile is erected into position. The missile is positioned either by special erectors built for the site and the missile or by a crane attached to a permanent gantry. At silos, missiles are positioned by a crane on the transporter, which lowers the missile into the silo; alternatively, missile stages are lowered by crane or winch into the silo and assembled inside it. A liquid-engine missile is fueled by means of pumps, tanks, pipes, and hoses. The guidance system is often aligned and calibrated by compasses and/or surveying equipment. The alignment operation may be performed initially and then regularly updated or updated just before launch. Many guidance systems are capable of self-alignment by sensing earth rotation. Prior to launch, target data and flight profile are loaded into the guidance system. Subsystem performance is verified by electrical and software testing equipment attached to the missile by cables from the control center. Missiles

Figure 12-1: Minimal launch pad with a gantry and connections to a complete rocket system.

maintained on alert are verified continuously. When the status of all responses is verified as satisfactory, the vehicle is ready for launch, and the launch sequence is executed on command. Unmanned air vehicles (UAVs), including cruise missiles, typically are designed for multiple launch platforms with standardized interfaces.

Typical Missile-Related Uses: Launch support equipment is required to prepare and launch missiles. Sometimes these devices continue to monitor and control the missile throughout all or portions of the flight profile.

Other Uses: Hydraulic systems, control electronics, computers, tanks and pipes, and communications equipment required for missile launching are similar, if not identical, to those required for numerous other purposes. Transportation, handling, erection equipment, and targeting and test algorithms are often unique to each missile, with no other uses. Silo-based launch support equipment is often unique to ballistic missiles and has no commercial uses.

Appearance (as manufactured): Launch pad facilities have a concrete apron, a relatively small stand upon which the missile is placed, and a gantry made of steel I-beams. A minimal system including a gantry and connections to a rocket is shown in Figure 12-1. Pads intended for military operations usually lack propellant storage, pumping, or handling facilities; these operations are conducted from tank and pumper trucks. They also lack permanent launch command, control, and system checkout equipment; again, these operations are conducted by equipment in trucks.

Appearance (as packaged): Pads, gantries, and silos are often built in place and rarely shipped assembled. Consistent with their size and weight, the electronic components and consoles are wrapped and sealed in padding to protect them from shock and moisture during transport and storage, and then packed separately in boxes or crates. The electronic equipment used in some small- to medium-sized launch control shelters is often installed in the shelter, and the whole shelter is mounted on a palette for transport. Some launch support electronic equipment is portable and has been reduced to the size of a suitcase.

(b) Vehicles designed or modified for the transport, handling, control, activation, and launching of the systems in Item 1;

Produced by companies in

- Australia
- Brazil
- China
- Egypt
- France
- Germany
- India
- Iran
- Iraq
- Israel
- Italy
- Japan
- Libya
- North Korea
- Pakistan
- Russia
- South Korea
- Spain
- Syria
- Ukraine
- United Kingdom
- United States

Nature and Purpose: Rockets and UAVs covered in Item 1 have been launched from trucks, trains, aircraft, ships, and submarines. Most launches, including launches from fixed sites, require vehicles, most often for transport and handling. Vehicles modified to carry, erect, and launch missiles are distinctive because they generally have no other practical use. Some of these vehicles, referred to as transporter erector launchers (TELs), provide a mobile launch platform independent of permanent launch facilities. Alternatively, some missiles and UAVs are carried and launched from (mobile) erector launchers (ELs or MELs), which are often towed by trucks known as prime movers. Vehicles modified to carry command-and-control equipment needed to activate, target, and control rockets or UAVs are also distinctive. Under subitem 12(b), the MTCR Annex controls the vehicle, including onboard equipment. Some of this onboard equipment (i.e., erector/launcher mechanism) would be controlled by 12(a) if removed from the vehicle.

Method of Operation: TELs and other mobile launchers perform the same preparation and launch functions as do the launch support facilities discussed in the preceding section. A TEL is usually loaded with its rocket(s) or UAV(s) by crane at a staging area. The crane may be part of the TEL. The TEL transports the rocket(s) or UAV(s) to the launch site, where it erects them to launch position. Some missiles are fueled at this point by separate tanker and pumper trucks; others may be transported already fueled. The launch crew makes electrical connections with the vehicle and ensures that all rocket or UAV subsystems are ready for launch. Targeting or flight plan information is loaded, and the guidance system is aligned and calibrated. When everything is ready, the crew launches the rocket(s) or UAV(s), often from a separate command-and-control truck.

Typical Missile-Related Uses: Relevant rocket systems or UAVs require vehicles designed or modified for the system such as TELs and associated command-and-control and support vehicles.

Other Uses: These vehicles, their hydraulic systems, control electronics, and computers and communications equipment are generally derived from a wide variety of commercial and military equipment.

Appearance (as manufactured): 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. MELs look more like elaborate dollies. Examples

Figure 12-2: Transporter erector launcher with a short-range ballistic missile erected.

Figure 12-3: An ICBM transporter erector launcher with the missile in a launch canister.

of both types of vehicles are shown in Figures 12-2, 12-3, and 12-4. Two versions of vehicles that carry and install ballistic missiles in their silos are shown in Figure 12-5.

TELs or MELs designed for UAVs are characterized by their relative simplicity and the presence of a launch structure (such as a rail or canister), which is sometimes inclined for launch. The launch structure can vary greatly in size and weight, depending on the UAVs to be launched. Launch structures can be as small as 2 to 3 m for hydraulic-assisted or rocket-assisted launchers of UAVs. Similar launch structures may be mounted on a tracked

Figure 12-4: An erector launcher detached from its prime mover.

Figure 12-5: Two different approaches to silo-based missile transporter and installation vehicles.

Figure 12-6: A transporter erector launcher for a large, Category II cruise missile.

Photo Credit: Teledyne Ryan Aeronautical

Figure 12-7: Rocket-assisted unmanned air vehicle erector launcher and its associated command-and-control van.

or wheeled vehicle. Four different approaches for UAV launchers are shown in Figures 12-6, 12-7, 12-8, and 12-9.

Examples of command-and-control trucks that accompany TELs and MELs are shown in Figures 12-10 and 12-11. A UAV command-and-control van is also shown in Figure 12-7. The command-and-control trucks shown in these figures could just as easily support fixed missile operations.

Figure 12-8: A transporter erector launcher used to transport and launch cruise missiles.

Appearance (as packaged): 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.

Figure 12-9: A pneumatic unmanned air vehicle launcher.

Produced by companies in

Relative Gravity Meters
- Canada
- China
- Germany
- Russia
- United States

Gravity Gradiometers
- United States

(c) 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 7×10^{-6} m/sec^2 (0.7 milligal) or better, with a time to steady-state registration of two minutes or less;

Nature and Purpose: Gravity meters and gravity gradiometers make very accurate measurements of the magnitude of the force of gravity at various locations. These data are used to create detailed maps of the earth's gravitational field for several kilometers around a ballistic missile launch site because local variations in gravity can cause inaccuracies in inertial guidance unless accounted for in the missile guidance software. Airplanes, helicopters, ships, and submarines outfitted with gravity meters can make gravity maps at sea. Airplanes and helicopters outfitted with gravity meters can make gravity maps over mountainous terrain. Gravity gradiometers can also be used as sensors in guidance systems to improve accuracy.

Figure 12-10: Command-and-control vehicles suitable for launching missiles from fixed or mobile locations.

Method of Operation: The methods of operation vary with the different types of equipment. Some accurately measure the fall time of a dropped mass; others use a set of pendulous electromagnetic force rebalance accelerometers that rotate on a carousel. Some are operated with the airplane, ship, or submarine in motion, and others are lowered to the surface of the land or sea floor to take a measurement. Systems designed to operate on a moving platform such as a ship or airplane need inertial navigation quality gyros and accelerometers for two-axis stabilization of the sensor platform. Systems designed to be lowered to the surface of the land or sea floor need only be self-leveling.

Figure 12-11: A deployed command-and-control truck used for ballistic missile operations.

Gravity gradiometers use a set of very high quality accelerometers on a precision rotating turntable. As the accelerometers rotate in a horizontal plane, they detect the subtle gravity differences about the perimeter of the turntable. The difference between the average readings taken on the east and west sides of the turntable, divided by the diameter of the turntable, yields the longitudinal gravity gradient.

Similarly, the difference between the average readings taken on the north and south sides of the turntable, divided by the diameter of the turntable, yields the latitudinal gravity gradient. Use of multiple accelerometers reduces the effect of individual accelerometer scale factor drift, and rotating the accelerometers about the perimeter virtually eliminates the effect of bias drift.

Typical Missile-Related Uses: Gravity maps for several to hundreds of kilometers in the area of ballistic missile launch sites are required for highly accurate systems. Airborne gravity meters can be used to map a large area of rough terrain or open sea adjacent to mountain roads or other areas where mobile missiles might operate. Ship or submarine-borne gravity meters are used to map the gravitational attraction beneath the sea to facilitate increased accuracy of ballistic missiles launched from submarines or from land installations near the coast. Because the effects of gravity variations in the launch area are rather small, gravity maps are primarily useful for ballistic missile systems that are already very accurate. Gravity gradiometers may be useful for UAV guidance, perhaps over water or other featureless terrain.

Other Uses: Gravity meters and gravity gradiometers are used in petroleum and mineral resource exploration and in geotechnical and environmental investigations. Gravity gradiometers are used as navigation aids on submarines.

Appearance (as manufactured): Gravity meters (gravimeters) and gravity gradiometers are high quality, sensitive electronic and mechanical instruments. Gravimeter appearance ranges widely because companies build them differently for different purposes. Systems fully integrated into a single case may be as small as 25 × 32 × 32 cm and weigh 14 kg. 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. The sensor unit of an air-sea gravity meter that is below the performance threshold established by the MTCR and is thus not MTCR controlled is shown in Figure 12-12. A complete, non-MTCR-controlled air-sea gravity meter system with mini-console is shown in Figure 12-13. Systems like the one shown in Figure 12-13 are MTCR controlled if they meet the performance criterion stated above.

Photo Credit: La Coste & Romberg

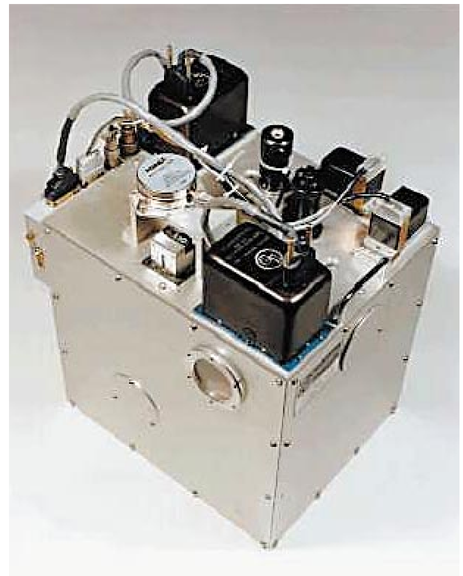

Figure 12-12: Sensor unit for a non-MTCR-controlled air-sea gravity meter.

Photo Credit: La Coste & Romberg

Figure 12-13: Complete non-MTCR-controlled air-sea gravity meter system with mini-console.

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.

Photo Credit: Scintrex Ltd.

Figure 12-14: A gravity meter that operates suspended from a helicopter. Its associated electronics, shown on the left, are installed in the helicopter.

Photo Credit: La Coste & Romberg

Figure 12-15: A non-MTCR-controlled gravity meter lowered by a ship or submarine.

Some have screens for observing the data collected in either digital or analog form; some have ports for printing hard copies of the data. Most have removable access panels. Batteries may be supplied to operate the system. Some systems have built-in computers and software. Some gravity meters are built to be lowered by a cable to the ground and operated from a helicopter, as shown in Figure 12-14. Others are built to be lowered to the sea floor by a ship or submarine; such a device, which is not MTCR controlled, is shown in Figure 12-15. Similar systems are MTCR controlled if they meet the performance criterion stated above.

Appearance (as packaged): 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.”

Produced by companies in

- China
- France
- Germany
- Israel
- Italy
- Japan
- Netherlands
- Russia
- South Africa
- Sweden
- Switzerland
- United Kingdom
- United States

(d) Telemetering and telecontrol equipment usable for unmanned air vehicles or rocket systems;

Nature and Purpose: Telemetering equipment involves sensors, transmitters, and receivers that send in-flight information on rocket or UAV performance to the ground. These devices allow engineers to monitor a vehicle’s flight, learn how it performs, or determine what caused any failure. Such equipment is used extensively during rocket and UAV flight testing. During flight tests, telemetry is normally collected throughout the entire flight. Telecontrol equipment that uses different sensors, receivers, and transmitters may be used to remotely control missiles or UAVs during powered flight. However, many operational ballistic missiles and cruise missiles fly autonomously; that is, without any telecontrol.

Method of Operation: Telemetering equipment installed in developmental rockets and UAVs monitor the important flight parameters (acceleration, vibration, control surface settings, etc.) and transmit these data to a ground station. The receiver decodes the data, displays them, and records them for playback later. Most operations are set up inside a building with an external antenna connection. If gimbaled, this antenna can pivot in three axes to track the rocket system or UAV in flight.

Photo Credit: Loral Microcom

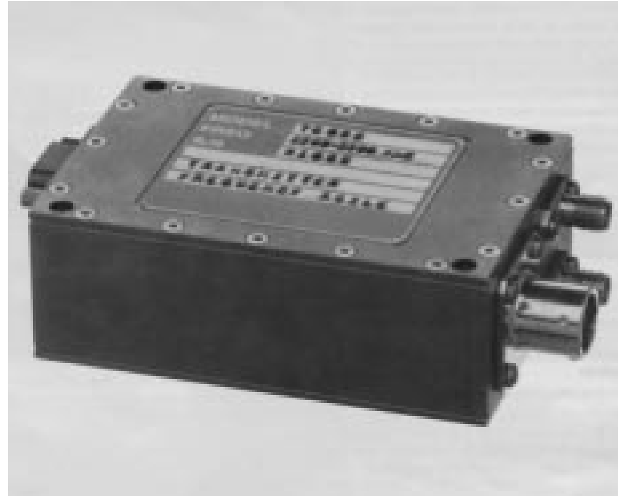

Figure 12-16: Telemetry transmitters for installation in flight vehicles.

Typical telecontrol systems are different for rocket and UAV systems. Rockets using command guidance are usually tracked by a radar near the launch site. Flight path data are processed to compare the actual and desired trajectory. If deviations occur, steering commands are sent from the ground station by radio to a receiver in the rocket system, which implements the commands to bring it on track. This command loop is maintained until the engines are turned off; the rest of the flight is ballistic. Telecontrol for UAVs is often implemented by a “man-in-the-loop” concept. A sensor such as a TV in the UAV transmits a visual image of the local terrain to a control van. A human pilot views this image and sends steering commands to the vehicle over the data link.

Photo Credit: SFIM Industries

Figure 12-17: A typical, but large telemetry reception antenna.

Typical Missile-Related Uses: Telemetering is important in the verification of performance during flight tests for both rockets and UAVs. Without such data, flight testing can be lengthy and expensive. Telecontrol is frequently used for UAV applications. Telecontrol is rarely used in ballistic or cruise missiles that carry weapons because the data link is vulverable to jamming or disruption.

Other Uses: Similar telemetry equipment is used to test commercial and military aircraft. It is also used in industry to collect data from remote sites and from chemical or other plants with a hazardous environment. It is also used in robotic land vehicles that must operate in hazardous environments.

Appearance (as manufactured): Telemetering equipment installed on flight vehicles is contained in small metal boxes with power, cable, and antenna connections. They have few distinctive features, as shown in Figure 12-16. The most notable telemetering equipment at the ground site is the telemetry receiving antenna. They are often large parabolic dishes that can rotate in two dimensions, as shown in Figure 12-17. Electronic equipment used at the ground site to demodulate, read, record, interpret, and display the telemetry looks like most rack-mounted scientific equipment or computers with few distinguishing features. Representative types of equipment are shown in Figure 12-18.

Telecontrol equipment installed in UAVs permits communication between the UAV and the ground station. Like telemetry equipment, this equipment is housed in metal boxes with power, cabling, and antenna connections, all unremarkable in appearance, as shown in Figures 12-19 and 12-20. Some UAVs communicate to their ground site by way of satellites and require special SATCOM antennas, as shown in Figure 12-21. A commercial satellite transceiver with streamlined antenna is shown in Figure 12-22. Another commercial system with a mechanically steered antenna is shown in Figure 12-23. The equipment for UAVs at the ground station is comprised of a flight control system (usually a joystick console), a video monitor, and recording equipment. A flight control station is shown in Figure 12-24; a portable video monitor is shown in Figure 12-25; and an integrated ground control system for a UAV is shown in Figure 12-26.

Appearance (as packaged): Because of the sensitivity of the electronics, telemetry equipment is usually shipped in cushioned

Photo Credit: In-Snec

Figure 12-18: Representative ground-site telemetry receiving and processing equipment.

Photo Credit: AAI Corporation

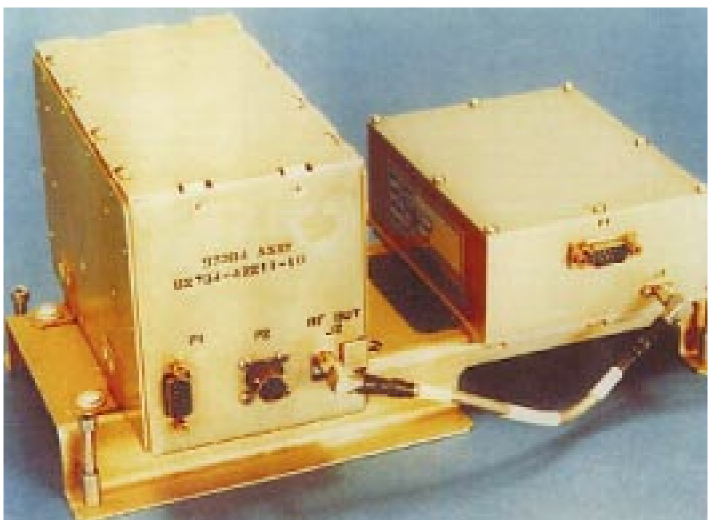

Figure 12-19: Unmanned air vehicle avionics. Left, a C-band transmitter; right, a UHF receiver.

Photo Credit: AAI Corporation

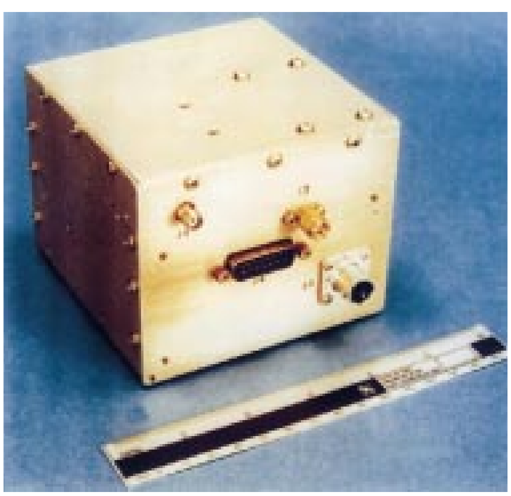

Figure 12-20: Unmanned air vehicle video and telemetry transmitter.

Photo Credit: General Atomics Aeronautical

Figure 12-21: A SATCOM antenna installed in an unmanned air vehicle.

Photo Credit: Racal Avionics

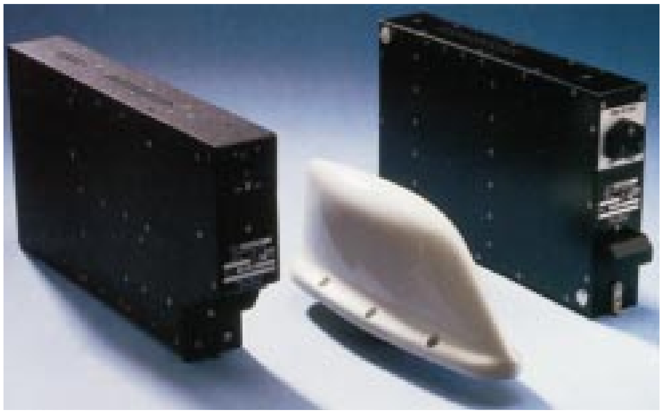

Figure 12-22: A commercial satellite transceiver with streamlined antenna.

Photo Credit: Racal Avionics

Figure 12-23: A commercial system with a mechanically steered antenna (streamlining not shown).

Figure 12-24: A portable flight controller console for an unmanned air vehicle.

Figure 12-25: A portable video monitor for displaying video transmitted from an unmanned air vehicle.

Figure 12-26: An integrated unmanned air vehicle control station.

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.

Produced by companies in

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

(e) Precision tracking systems:

(1) Tracking systems which use a code translator installed on the rocket or unmanned air vehicle in conjunction with either surface or airborne references or navigation satellite systems to provide real-time measurements of in-flight position and velocity;

(2) Range instrumentation radars including associated optical/infrared trackers and the specially designed software therefor with all of the following capabilities:

(i) an angular resolution better than 3 milli-radians (0.5 mils);

(ii) a range of 30 km or greater with a range resolution better than 10 metres RMS;

(iii) a velocity resolution better than 3 metres per second.

(3) Software which processes post-flight, recorded data, enabling determination of vehicle position throughout its flight path.

Nature and Purpose: Precision tracking systems produce accurate records of rocket system trajectory or UAV flight path. Engineers use these data to help determine vehicle performance and the causes of any vehicle failure. Range safety engineers also use these data to monitor the missile flight path. If the missile veers into an unsafe trajectory, it is destroyed. Precision tracking systems can be used in conjunction with, or as an alternative to, telemetry equipment, which sends back data on vehicle acceleration time history, from which missile trajectory can be reconstructed.

Method of Operation: Code translators installed on a rocket or UAV process signals received from ground or satellite transmitters. Those signals carry timing data that allow the code translator to determine the distance to each transmitter. These data are sent back to the ground site on a different downlink frequency. Because the transmitters are in known locations, the ground site can accurately determine missile position and velocity. These data can be displayed in real time or recorded on magnetic disc or tape.

Range instrumentation radars are also used to determine missile position and velocity. Usually a radar with a wide field-of-view is used to track the approximate vehicle location, which is then used to aim radars with a narrow field-of-view, optical trackers, or infrared trackers capable of determining missile angle, range, and velocity with the required precision. These data are recorded as they occur, along with an ongoing record of the time. A variation on this approach is to install in the flight vehicle a small transmitter that broadcasts or a transponder that receives and re-broadcasts at the radar operating frequency and thereby provides a beacon that allows the radar to track the vehicle more easily.

Figure 12-27: A mobile phased array missile tracking radar.

No matter how the data are collected, to be useful, information on time and position must be interpreted. Post-flight data processing may take place anywhere, but it is often conducted in the telemetry data processing center where real-time data are received and recorded. These recorded data are read, filtered, and processed. The processed tracking data are then re-recorded on disk or tape for further analysis or output plotting.

The post-flight and recorded data processing software typically consist of mathematical filtering software routines that process the previously recorded data in order to provide a smooth estimate of the vehicle trajectory. This processing software is used both to provide the estimated vehicle position data for periods of time when a real-time data outage may have occurred and to perform filtering in order to get the best estimate of the trajectory. Many different types of mathematical filter implementations are used, varying from the simplest such as a straight-line interpolation between data points, to more sophisticated polynomial-based filtering such as spline-fit filtering. Some filtering routines also use Kalman filtering to post-process these data, although the Kalman filtering is normally used for real-time tracking applications because of its ability to use simplified matrix manipulations to arrive at tracking solutions.

Typical Missile-Related Uses: Precision tracking systems and range instrumentation radars are helpful during the testing phase of the flight program to determine whether the missile is traveling along the predicted trajectory and to monitor missile flight for any anomalies. Such information is used to evaluate and improve the performance of numerous subsystems. The software that processes post-flight recorded data and thereby helps determine vehicle position throughout missile flight path is essential to interpretation of those flight data.

Other Uses: These systems can be used to support commercial and military aircraft testing and the development of weapons, including artillery and small rockets. Industry uses post-processing of data to evaluate events after the fact, such as race car performance.

Appearance (as manufactured): Precision tracking systems and range instrumentation radars look like ground-based portions of telemetering and telecontrol equipment. They include familiar dish-type radars as shown in Figure 12-17, as well as phased-array radars, which are characterized by their flat (rather than dish) surface as shown in Figure 12-27. Also used are

Photo Credit: Contraves

Figure 12-28: An optical missile tracking telescope.

Photo Credit: Contraves

Figure 12-29: An optical missile tracking system.

optical devices that look like telescopes as in Figure 12-28; large robotic binoculars as in Figures 12-29 and 12-30; and laser tracking systems that resemble optical instruments as shown in Figure 12-31.

Photo Credit: Contraves

Figure 12-30: An optical missile tracking system.

Photo Credit: Contraves

Figure 12-31: A mobile laser missile tracking system.

The precision tracking system hardware (transponders) carried aboard rockets or UAVs are generally very small electronics enclosures that vary from 800 to 2,500 cm^3. They are generally solid, environmentally sealed enclosures with external power and antenna connectors. The only subelement of these transponders is the antenna element, which is normally located on the external surface of the rocket or UAV.

Appearance (as packaged): 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. All optics are protected with environmental covers.