ANALYSIS OF CRUISE MISSILE VULNERABILITY WITHIN THE CONTEXT OF THE SYSTEMS ENGINEERING PROCESS

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(ABSTRACT)

Anti-shipping cruise missiles are likely to pose a serious threat to U.S. Naval forces in any future conflict. In order to adequately defend their assets, the U.S. Navy needs to develop the means to defeat these systems. To do this, it needs to define and exploit any vulnerabilities associated with them.

The Systems Engineering Process is used to define the vulnerability of a generic cruise missile system. Initially, the requirement for a vulnerability analysis is established. The functions associated with cruise missile systems are presented, to a level in which components are identified. Existing systems are then compared, providing a means in which a "typical" system can be identified. The failure modes for this system are then defined.

Finally, a computer model of the missile is constructed and analyzed, leading to numeric values for the measures of vulnerability to fragmenting warheads.

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Introduction

The success of Operation Desert Storm created a false sense of security in the West. Iraqi forces were unable to mount a serious offensive threat to coalition Naval forces. This situation is not likely to translate into the future. Due to technical advances, limited defense budgets, and active arms markets, U.S. naval forces may encounter serious threats in the form of anti-shipping cruise missiles. These weapons are lethal and increasingly prolific. To make matters worse, existing defenses may be embarrassingly inadequate.

This report is concerned with the measures of anti-shipping cruise missile vulnerability. It is divided into two sections. The first section provides background information on both parts of the report title; vulnerability and cruise missiles. The second section involves exercising an analysis of a generic, yet practical, cruise missile design.

The system in this case can be looked at in terms of a military conflict. There are two opposing forces, and the system, as shown in Figure 1, can be defined on many levels. *Total Conflict*, between a foreign nation and the United States, comprises the top level. A *Theater* level system includes the armed forces of both sides and is limited by geography (although the theater may cover an entire hemisphere). *Naval Actions*, which comprise the third level, may play a dominant role in theater operations. The *Operations*, or *Task Force*, level involves the interactions of groups of surface combatants, submarines, amphibious forces and aircraft. The *Unit* level is concerned with the interaction of task force elements. In this case, the interaction is between incoming foreign cruise missiles and a U.S. Navy surface ship. Finally, this interaction is limited to one attacking cruise missile and the warhead of a defending surface-to-air missile launched from a ship.

Both elements of this system must be designed, produced, maintained and operated. This report looks at the interaction between these elements, which occurs during their operational phases. In these phases, the cruise missile is being fired at a ship and the warhead is detonating to damage the missile as a means of preventing it from hitting its target.

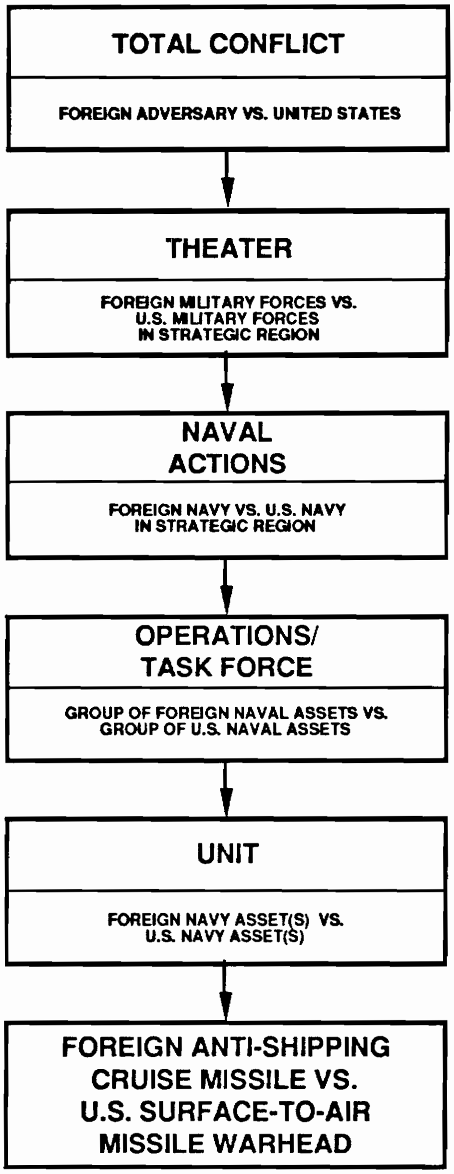


Figure 1: System Level Definition For Cruise Missile Vulnerability

The *measure of effectiveness* of the cruise missile is the primary concern of the vulnerability analysis. This is defined as the number of missiles hitting the target/number of missiles fired or, if single missiles are considered, the probability of a missile hitting a target. This could be expressed as follows:

measure of effectiveness = (1-susceptability*vulnerability)*prob(hit/survival)

Susceptability (designated P_h) refers to the probability of the missile being hit by a damage causing mechanism. *Vulnerability* (designated $P_{k/h}$) refers to the missile's inability to withstand damage. These two measures are dependent on the capabilities and characteristics of the missile and the means intended to damage it. The *probability of hit/survival* refers to the probability of the missile to hit the target in the absence of damage mechanisms.

Ideally, the Navy would like to keep the measure of effectiveness as low as possible. Realistically, a value of zero would not be practical. A factor of 0.05, however, would be considered a reasonable objective.

The "problem" from the perspective of the surface ship could be identified as finding a means of preventing an incoming missile from completing its mission. Preventing a missile from sinking a ship involves identifying and exploiting any vulnerabilities in the missile and its subsystems. This can be accomplished through either countermeasures or kill mechanisms. Countermeasures are more likely to affect the sensor and guidance systems, while kill mechanisms affect every subsystem. In most cases, only a few components need to be damaged to disable an entire system. Often, rendering one subsystem inoperable would be sufficient to prevent the missile from completing its mission.

There is an old saying that recommends "knowing your enemy" if you hope to be successful in defeating them. Cruise missiles are flexible weapons that can be launched from surface ships, submarines, aircraft or land-based positions. A wide, and growing, variety of these systems are currently in service. By most indications, these systems are quite effective. Compared to ships and attack aircraft, in terms of money and human safety, they are a bargain. They are deadly as well, to which experience in the Falklands and the Persian Gulf can attest.

Cruise missiles, despite their capabilities (and reputation), have weaknesses. To determine these weaknesses, the physical and functional characteristics of the specific target must be carefully analyzed. In doing so, it can be seen that cruise missiles can be looked at as systems that are composed of several subsystems. These subsystems include: a) propulsion systems, b) sensor systems, c) guidance systems, d) control systems, e) warheads and f) airframe. The missile operates as the result of these various subsystems working together.

There are a number of design paths which are followed in the cruise missile design process. As a result, there is a wide spectrum of viable threats to be considered; for example, missile cruise speeds vary greatly (from subsonic to mach 5+). Of course, architectural details, such as propulsion systems (solid rocket, liquid rocket, turbojet, turbofan and ramjet), sensors, guidance packages and warhead characterization differ considerably, as well.

Although the above characteristics contribute to the effectiveness of a missile system, there are no definitive guidelines into which details make for better missiles. It all boils down to the limits of mission objectives, technology and defense budgets. In short, the design and production of a type of missile is the result of a systems process.

The procedure followed during this study to analyze cruise missile vulnerability is shown in Figure 2.

The first section of this report looks at the vulnerability analysis process from a Systems perspective. The threat to Navy ships by cruise missiles is defined and an overview of missile architecture is presented. The need for proper analysis of missile systems, both current and future, is then presented. A functional analysis is then conducted to determine the arrangement and operational characteristics that are typical for cruise missile systems. Next, a specific target is defined by comparing the characteristics of existing systems. Finally, the failure modes of this target are analyzed by developing a Failure Modes and Effects Analysis (FMEA) and by performing a Fault Tree Analysis (FTA).

The second part of this report involves the results of applying the principles of vulnerability to a generic missile target. This target is based on existing systems and represents a viable threat. The damage mechanism applied here, HE fragmenting warheads, is the most probable, but not exclusive, defense against missiles. The analysis consists of modeling the target, determining which subsystems and/or components are vulnerable, determining the degree of this vulnerability, and finally, quantifying the vulnerability of the missile to fragmenting warheads.

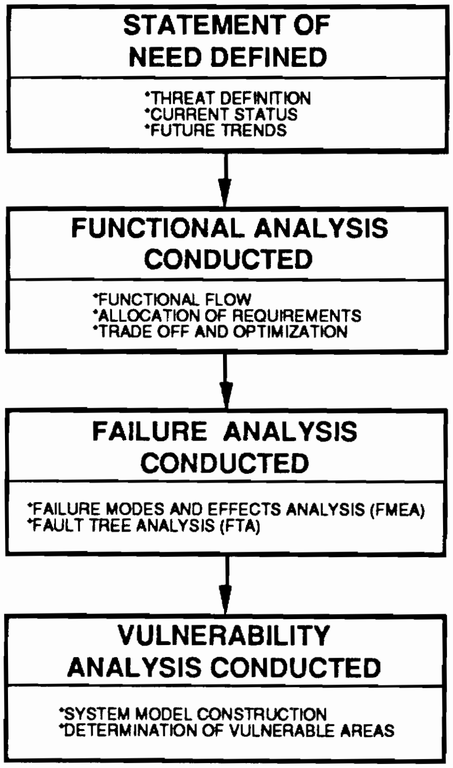


Figure 2: Process For Analyzing Cruise Missile Vulnerability

This analysis took only hard kill mechanisms into account. Countermeasure techniques are a viable means of defeating missiles, but follow a completely different methodology, and a thorough explanation of them was beyond the scope of this report.

1.0 Statement of Need

The first step in conducting a systems engineering approach to evaluating cruise missile vulnerability is identifying the system need. In this case, the need of the system is exactly the opposite of the need of one of its elements. The need statement of this element, the missile, could be stated as follows: the missile must be able to find, track and reach a target, and inflict as much damage as possible upon reaching it. The system need statement could be written as follows: We must prevent the missile from finding, tracking and reaching its target, or prevent it from inflicting an amount of damage that is sufficient to disable its target. To satisfy this basic need at least 95% of the time, the Navy can concentrate on defending against missiles before, during or after launch.

Defending against missiles by preventing them from being launched in the first place, by attacking the launch platform, requires the adoption of a "shoot-first", or "defense through good offense" policy. This policy makes sense in the frame of a total war scenario, provided the launch platforms could be located in time. Unfortunately, this is not always the case. Furthermore, destroying all platforms is a difficult task. Invariably, a certain number of missiles are likely to be launched.

Realizing that the HMS Sheffield was virtually destroyed by an Exocet missile *that did not detonate*, expecting to minimize damage after being hit by a missile is difficult. Hardening ships by installing armor is expensive, and the additional weight on topdeck structures has adverse effects on stability. Installing defensive compartments and designing for survivability is a worthwhile pursuit, but only partially successful against missiles that may carry warheads that weigh in excess of 500 lbs (225 kg).

Consequently, the Navy needs to look at the threats that it may encounter. Once these threats have been identified, ways to engage them en route to their targets must be determined. To do this, the Navy needs to analyze the operational characteristics of these threats, determine their vulnerabilities, and exploit these vulnerabilities by deception techniques and/or hard kill mechanisms. The results of this analysis should remain valid for the life cycle of the missile (10-15 years), and the process should remain flexible enough to account for modifications in missile physical and functional characteristics.

Most of the vulnerability analysis being conducted on new missile systems is based on knowledge of existing systems. In many cases, this approach is valid. Unfortunately, reliance on these methods should not be taken for granted. Systems, and the means to defeat them, change as the result of technological and economic factors. For this reason, a process that analyzes cruise missile systems, beginning from the basic level and proceeding in depth and detail, needs to be implemented.

1.1 Definition of Threat

It is estimated that anti-shipping cruise missiles pose the greatest threat to the surface forces of the U.S. Navy. The reasoning behind this is two-fold. First, missiles are potent weapons. They are hard to detect, hard to intercept, and are capable of inflicting serious damage to ships. Secondly, as the result of economic factors, they are proliferating into an ever-growing number of second- and third- world arsenals.

During the Gulf War, The USS Princeton was essentially crippled by one mine. Public reaction to a $1.0 Billion+ ship being disabled by a product of 19th century technology was less than enthusiastic. Cruise missiles are more modern, and even more lethal than mines. The Navy would have much to answer for if it did not have a means of defense for its assets.

1.1.1 Characteristics of Cruise Missiles

Cruise missiles come in all shapes and sizes. This section is included to present an overview of the architecture and operational characteristics of cruise missiles.

1.1.1.1 Structure

The structure of the missile is designed to support the internals, such as warhead, guidance and propulsion subsystems. It must be strong enough to withstand forces of motion (weight, lift, thrust and drag), yet light enough to not contribute significantly to those forces. The weapon must be shaped for optimum efficiency, yet must take into account the constraints imposed by storage facilities, launch mechanisms and platforms.

In their most complicated forms, cruise missiles are constructed like aircraft, with a weight bearing frame and an external skin. This method is seldom used by modern missiles, however. Instead, most viable threats are small (15' - 25' (4.5-7.6 meters) long) and monocoque in shape, with the outer skin (usually steel, aluminum or titanium) held in shape by bulkheads and occasional stiffeners.

Missiles are fitted with sets of lifting and control surfaces that provide the means to alter the angle of attack. The location and configuration of these foils can significantly alter the performance characteristics of the missile. Smaller, "skid-to-turn" missiles feature a forward set (usually 4) of fixed wing surfaces and an aft set of variable control surfaces. Some missiles, such as Tomahawk and Styx, fly much like aircraft, using a pair of horizontal wings for "bank-to-turn" control.

1.1.1.2 Propulsion

The objective of the propulsion system in cruise missiles is to obtain thrust by generating rearward momentum in the form of exhaust gases. Rockets create this flow in a manner that uses working fluid that is carried onboard the vehicle, while air breathing engines rely on external sources for propellant gas.

There are two types of rockets being utilized in cruise missiles: liquid propellant and solid, or hypergolic, propellant. Liquid propellant systems have the fuel and oxidizer components carried in low pressure tanks. They are capable of being throttled. They do however, require "plumbing" in the form of pumps, and fuel lines, and the components tend to be corrosive and volatile. Solid rockets are simple in design. Essentially, the entire rocket motor serves as the combustion chamber. Solid rockets , however, are self-sustaining and burning rate is not controllable.

Turbojets, turbofans and ramjets fall into the category of air breathing engines. All engines of this type operate on the following principles: i) air must be injected, ii) propellant must be supplied, iii) combustion must occur and iv) products must be ejected. The high temperature and pressure of the exhaust gases provide kinetic energy to the air flow trailing the missile. Gas turbines are best suited for operation at transonic and supersonic speeds while ramjets are best when operating at high supersonic speeds.

Ramjets are simple in design (no moving parts) and efficient at high speed. A basic ramjet consists of a cylindrical tube, open at both ends, with an interior fuel-injection system. The ramjet operates by taking high speed, low pressure air in through a diffuser section. The diffuser converts this air to high pressure, low speed air flow. This flow mixes with fuel, which is continuously sprayed into the engine by injectors. Spark plug-like devices called initiators commence burning, with subsequent burning being uninterrupted and self-supporting. Ramjets are unable to develop thrust while at rest, so a booster system must be used to accelerate the missile to near its operating speed.

Turbojets utilize high-pressure compressors that are turbine driven (with a fraction of the exhaust gases running the turbine). The major components of a turbojet engine are the inlet, compressor, combustor, turbine and nozzle. Inlets capture air from the freestream and may decelerate it to provide uniform, subsonic flow to the compressor. The compressor is used to increase the pressure of this air. Combustors operate by having fuel sprayed into a centralized region where the fuel evaporates and the fuel ignites. Exhaust nozzles focus the high pressure exhaust gas and thus control the kinetic energy and reaction force on the missile.

Turbofans are extensions of the turbojet concept. Turbofans are generally more efficient than turbojets, as they utilize a second stage of turbine blades to extract additional energy from the gases aft of the compressor turbine.

In addition to propulsion related components, turbojets and turbofans require lubrication, cooling, and accessory drive subsystems. The lubrication subsystem is usually a self-contained pressurized oil system (composed of tanks, pumps, lines and coolers that lubricates bearings and accessory drives. The engine cooling subsystem may utilize a closed, pressurized liquid system, fuel, or freestream air to prevent engine components from being damaged by thermal stress. The accessory drives provide power to the other various subsystems.

Currently, all of the above systems are used; however, the majority of missile systems use either solid rockets or turbojets. Ramjets have been come into greater use recently. Future systems can be expected to make further use of these systems.

1.1.1.3 Guidance and Control

Guidance and Control is the means in which a missile tracks, and ultimately intercepts, its target. The specifics of how this is accomplished vary, not only from missile to missile, but also where the missile is located in its flight path. Every missile guidance and control system consists of an attitude control system and a flight path control system. The attitude control system is responsible for maintaining the missile in the desired attitude by controlling pitch, roll and yaw. The flight path control system determines the flight path necessary to intercept the target and issues commands to the attitude control system to maintain that path.

The line of sight (LOS), which refers to the line between the sensor and the target, is the crucial measurement of any terminal guidance package. The parameters associated with this measurement are target azimuth, elevation, range, and relative velocity. The difference between this line and the tracking line (the "line" in which the missile is traveling) is considered the error. The guidance and control system is heavily reliant on feedback, with corrective adjustments being made when a guidance error, or missile instability, is present. Guidance and stabilization corrections are combined and the result is applied as an error signal to the control system. The control system is "driven" to respond to this error until the tracking line becomes incident with the LOS.

The primary components associated with the attitude control system are the devices for measuring attitude and motion, the autopilot, and the control surfaces. The flight path control system is a computer, which may or may not be located on board the missile. The control surfaces are wings or fins that work to regulate airflow over the air frame. Their controlling mechanisms are usually hydraulic or electrical.

There are usually three missile guidance phases: boost, midcourse and terminal. The boost phase usually refers to the early stages of flight, at or near launch. Essentially, "guidance" during this phase involves having the missile clear the launch platform and being placed in a position in which it can either see the target or receive external guidance signals. The likelihood of intercepting the missile during this phase is remote, however.

The midcourse phase of guidance is the longest in both time and distance. Corrections may be necessary to bring the missile onto and maintain the desired course. Several means may be used to provide information to the guidance system. The midcourse phase usually ends when the missile is near the target, and the terminal phase begins. Midcourse guidance can either rely on control guidance systems (using a combination of internal and external components), or self contained systems (using exclusively on-board components).

With self contained systems, all guidance and control equipment is located on board the missile. In cruise missiles, these systems usually utilize an inertial navigation package. These systems are responsible for placing the missile in a predetermined location, with the missile's flight path constantly being corrected by means of gyro-stabilized accelerometers. Most missiles utilize three types: to measure vertical, lateral and longitudinal accelerations (to measure altitude, azimuth and range respectively). Desired values are compared with measured values, and if necessary, correction signals are sent to the control system.

The terminal guidance phase requires a highly accurate, fast-response, system of sensors and controls. The sensors usually home in on a signature of the target. Active radar is the most common type of sensor, although infrared, passive radar and optical systems are used as well. The missile is guided on the basis of electromagnetic radiation contact with the target. Azimuth and elevation of the target are required for homing to be successful. Guidance can be either active, semi-active or passive with reference to a line of sight sensor. Active systems contain both the transmitter and receiver. An on-board computer calculates a course to intercept the target and sends steering commands to the autopilot. Semiactive homing relies on a tracking radar that is located at the launching sight. The missile is equipped with a receiver only, and uses reflections from the target to formulate an intercept path. Passive homing relies on energy that emanates from the target (such as heat or radio transmissions) for guidance.

Radar uses electromagnetic waves to remote-sense the position, velocity and identifying characteristics of targets. Most missile guidance radars are essentially specialized tracking radars. The basic parameter measured by the tracking radar is the line of sight between the antenna and the target. There are usually two types of radar used in anti-shipping cruise missiles: pulse and pulse-doppler.

Pulse radars illuminate targets by transmitting short bursts of energy and listen for echoes while the transmitter is silent. In the case of directional antennas, the line of sight to the target can be accurately determined. Target range is determined by measuring the time it takes for the pulse to return and multiplying that number by the speed of light (the velocity of the wave) and dividing by 2 (to account for round-trip travel).

All radars operate in accordance with the same principles. Performance, on the other hand, varies considerably. Essentially, all pulse radar systems have the following components in common: antenna, antenna servo, synchronizer, modulator, duplexer, transmitter, receiver, receiver protection device, and power supply.

The *antenna* concentrates the signal into a narrow beam that is radiated in a single direction. The antenna is steerable, by means of the *antenna servo*. The *synchronizer* times the transmission of the radar pulses. The modulator provides input power to the transmitter. The *duplexer* is an electronic device which switches single antennas between the transmit and receive modes. The *transmitter* generates the radar signal. The *receiver* intercepts and amplifies the echo signals.

Pulse doppler radars are specialized versions of pulse systems. Pulse doppler systems utilize most of the same components as pulse systems. They do, however, feature the following innovations: highly versatile transmitters that are capable of measuring doppler frequencies (and thus, velocities), the use of digital signal processors for high speed signal processing, the use of radar data processors to control and monitor all elements of the system, and the integration of the radar into the inertial navigation system.

The components associated with pulse doppler systems differ from pulse systems in the following: the modulator is eliminated, with its functions being performed by the transmitter, a component, called the exciter, is used to establish the radio frequency of the transmitter, the synchronizer is eliminated, with its functions being performed by the radar data processor.

Since no one system is ideal for all phases of guidance, composite systems are often used. For example, inertial guidance may be utilized during the midcourse phase, with homing guidance used during the terminal phase.

1.1.1.4 Flight Paths

Flight paths are determined by the guidance system. They can be either preset or variable. Preset flight paths can be either constant or programmed. Variable flight paths rely on target position and velocity. The four basic types of variable flight paths are pursuit, constant-bearing, proportional navigation and line of sight. The pursuit type of flight path strives to keep the missile pointed at the target at all times. Constant-bearing flight paths aim at the point in which the missile expects to intercept the target. Changes in target heading and velocity are accounted for by continuously recalculating the aimpoint. Proportional navigation takes into account changes in the line of sight. These changes are passed on to the computer, which generates steering commands for the autopilot. Line of sight flight paths follow along the LOS between the launching platform and the target.

The actual profile of flight varies from missile to missile. Most slower (high subsonic) missiles travel at low altitude to avoid detection. At the terminal phase, they may maintain this profile or they may execute a series of maneuvers to evade defenses or to intercept a specific area of a ship. High speed missiles may cruise in at a high altitude, and dive in, using speed as a defense, to intercept their target.

1.1.1.5 Munitions

The munitions, or ordnance, system refers to the means which the missile uses to complete its mission (damaging a shipping target). This involves i) a container to hold the damage mechanisms, ii) the damage mechanisms themselves, which could be fragments, or blast or incendiary devices and iii) a means of deciding when to release the mechanisms. Cruise missile munitions usually fall into the category of warhead/fuse systems, although some systems consist of kinetic energy penetrators or explosive submunitions.

Warheads usually consist of a hard outer casing (usually made of steel or some other high hardness metal) filled with high explosive, a central core initiator, and fusing devices. Depending on the warhead shape and orientation, the ordnance system can be designed to detonate after penetrating the target, at impact, or at close proximity to the target (usually just above). Fuses can be located in the nose area to detonate on impact or a set time afterwards or they can be timed in accordance with the guidance system. The characteristics of the case and explosive are instrumental to the lethality of the warhead. Fragment size and velocity can be dictated by geometry and scoring on the surface of the case as well as the amount and type of explosive charge.

Cruise missiles fitted with submunitions utilize a release mechanism to eject penetrators or bomblets over a wide area. Although the area in question is usually associated with ground forces or airfields, the concept may be applied in the anti-shipping role.

1.1.2 Overview

The threats to U.S. Navy ships are diverse. Incoming missiles may be traveling at high subsonic speeds to speeds in excess of Mach 5.0. They may be traveling just above the surface of the waves, executing evasive maneuvers, or they may be executing a steep terminal dive. They may be using rockets, turbojets or ramjets, guided by active radar, to reach the end of their mission. To properly defend its assets, the U.S. Navy needs to look at all of these possibilities.

1.2 Current Status

Currently, both deceptive techniques and hard kill mechanisms are in use by the U.S. Navy. Deceptive measures involve using physical or electronic means to disorient or mislead the guidance system of an incoming missile. These techniques can be relatively effective, but a thorough presentation of them is beyond the scope of this report.

Hard kill mechanisms, on the other hand, involve intercepting the missile with high energy projectiles so as to inflict enough damage to prevent the missile from reaching its target. The problem amounts to knowing how much energy is required, and at what location to apply it.

A number of systems, such as Phalanx and Standard missile, are currently envisioned in the hard kill role. New projectile and warhead designs are constantly being proposed. In each case, the energy distribution of projectiles or fragments is known or estimated with reasonable certainty. Knowing where to deliver these particles (as penetrators) requires a knowledge of the arrangement and operational characteristics of the incoming missiles.

Finding accurate and detailed information about potential threats is difficult, and reliance on previous knowledge is not always valid; thus, a process needs to be followed to determine the vulnerability of various cruise missile systems to existing or postulated defenses. This requires identifying, in order, the missile functions, missile components, possible failure modes, component vulnerability, and ultimately, the system vulnerability.

1.3 Future Trends

It is expected that cruise missiles will continue to pose a serious threat well into the next millennium. Future systems could be expected to be faster, more maneuverable and harder to detect. Hard kill mechanisms will remain a viable means to counter this threat. For this reason, vulnerability analysis will remain a vital tool.

1.4 Conclusion

Despite the various approaches to cruise missile design, all systems have the same intention. They must find, track and fly to a target before they can damage it. Defeating these systems, through deception, or hard kill, requires knowledge of the system's vulnerabilities. By defining the need statement, we have shown that we have a definite requirement to determine the vulnerability of cruise missiles. A detailed analysis of how the system functions is required to determine these vulnerabilities.

2.0 Functional Analysis

Quite often, the Systems Engineering Process involves identifying a need, proposing a means to satisfy that need, and designing a system to accomplish these means. In the case of analyzing cruise missile vulnerability, the need, (preventing cruise missiles from reaching and damaging U.S. Navy ships) and the means (hard kill mechanisms exploiting vulnerabilities) seem to fit this process. The "designed system," however, is not involved in accomplishing the means. Instead, this system is the *recipient* of the means. Furthermore, this system is usually designed, produced , and operated, under different conditions, by an adversary.

In the case of a Systems Engineering approach to cruise missile vulnerability, the system under analysis may already be in existence. Even so, there is not great deal of information available about how the system is arranged or operates. To determine these characteristics, a functional analysis is performed.

Functional analysis involves identifying system operational and support requirements and translating them into specific design requirements. This translation is accomplished through the development of functional flow diagrams. The functional approach is used as a basis for identifying design requirements for each level of the system.

Functions usually fall into the operational or maintenance categories. When analyzing cruise missile systems, maintenance is not an overwhelming factor, as a missile is only required to be used once. Maintenance functions are limited to keeping the missile ready to be launched on demand. This usually involves keeping the missile stored, usually in storage canisters, at facilities or on ships that protect the missile from the effects of its environment. These facilities must be located to insure rapid availability and maintain security.

The most important functional concerns, from a vulnerability standpoint, are operational functions. Operational functions are those functions that are associated with fulfilling mission requirements.

2.1 Development of Functional Flow Diagrams

Functional flow diagrams present system requirements in functional terms. Constructing them begins with a definition of what the system must accomplish. Subsequent layers provide more detail into what is being done within the system. Ultimately, the diagram is detailed enough so that individual components can be identified.

The top level of a functional flow diagram shows all of the gross operational functions that must be performed in order for a system to accomplish its mission. The warhead functions are limited to fusing, detonation and fragment dispersion. A typical cruise missile, from the perspective defined here, is more complicated. The top level functional flow diagram for this element is presented in Figure 3.

These functions are arranged in series. Thus disrupting any of these functions will result in the missile being unable to complete its mission, which from the vulnerability standpoint, is a successful mission.

At this point, no components, or subsystems, are clearly defined. In the second level, the system functions that are required for the gross functions to be accomplished are identified. At this level, the various systems become apparent.

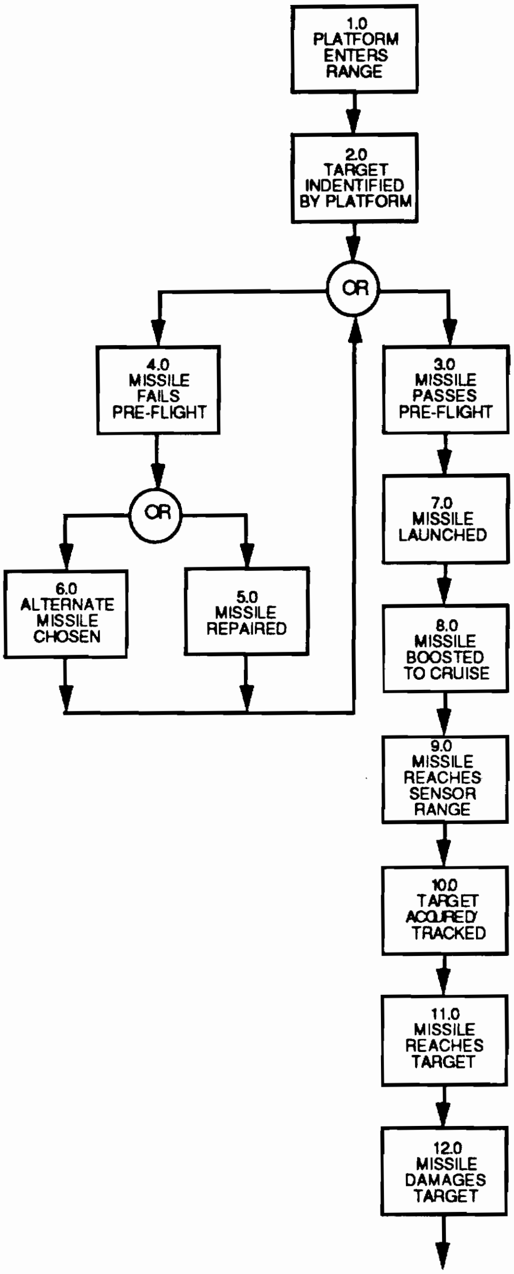


Figure 3: Top Level Functional Flow For A Cruise Missile System

At the operational level, the first function in Figure 3 is identified as "launching platform reaches the proper launch range". The launch platform is either an aircraft, a surface ship, a submarine, or a land based platform (which can be mobile or fixed). To accomplish the gross function, these platforms must remain capable of launching offensive weapons. Preferably, they remain undetected, although damage is the true intention here. From the vulnerability standpoint, the objective is to prevent the platform from reaching a point where they can launch missiles.

The second function in Figure 3 is "target is identified by launch platform". Usually, some type of sensor is used by the launching platform. These are usually search radars, although acoustic (sonar), and visual (reconnaissance) means are also employed. The vulnerability intention is to prevent detection, either by deception, jamming or physical elimination of search systems.

The third through sixth functions in Figure 3 involve preflight preparations for the missile. This requires the missile to be taken from the stored state, passing preflight inspection, and then being placed into the launch system. The mechanisms are missile and platform specific. In the event of aircraft launch, missiles must be loaded onto launch rails (tactical attack aircraft) or into bomb bays (for strategic or intermediate range bombers). Surface ships require the missile to be mounted on rails, box launchers or vertical launch systems. Submarines require missiles to be loaded into torpedo tubes or vertical launching tubes. Land based systems require missiles to be loaded onto rails or box launchers. Vulnerability concerns include damaging the launching systems to prevent missiles from being loaded.

The seventh function in Figure 3 is "missile launched" by platform. The launch system must function properly and the missile's propulsion system must be initiated. From a vulnerability standpoint, the launch system must be rendered inoperable, or the missile's propulsion system must be damaged. The flow diagram for a turbojet propulsion system is shown in Figure 4. At this level we are able to identify the principal components of the propulsion system are identified.

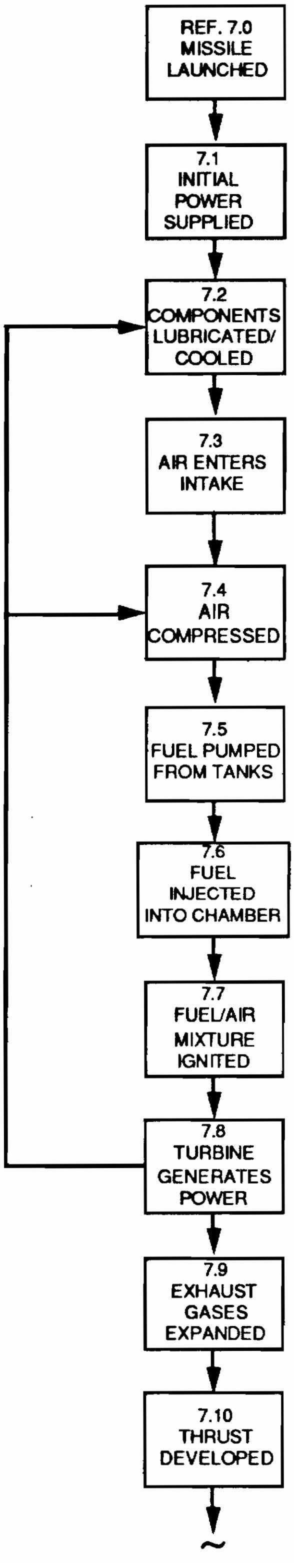


Figure 4: Second Level Functional Flow - Missile Launch to Cruise

The eighth function in Figure 3 is "missile boosted to cruise." Many missiles must be accelerated to a cruise velocity. This is usually accompanied by the missile reaching a desired altitude. The function flow diagram is shown in Figure 5. This function is dependent on both the propulsion and control systems. The vulnerability consideration here is to damage either of these systems.

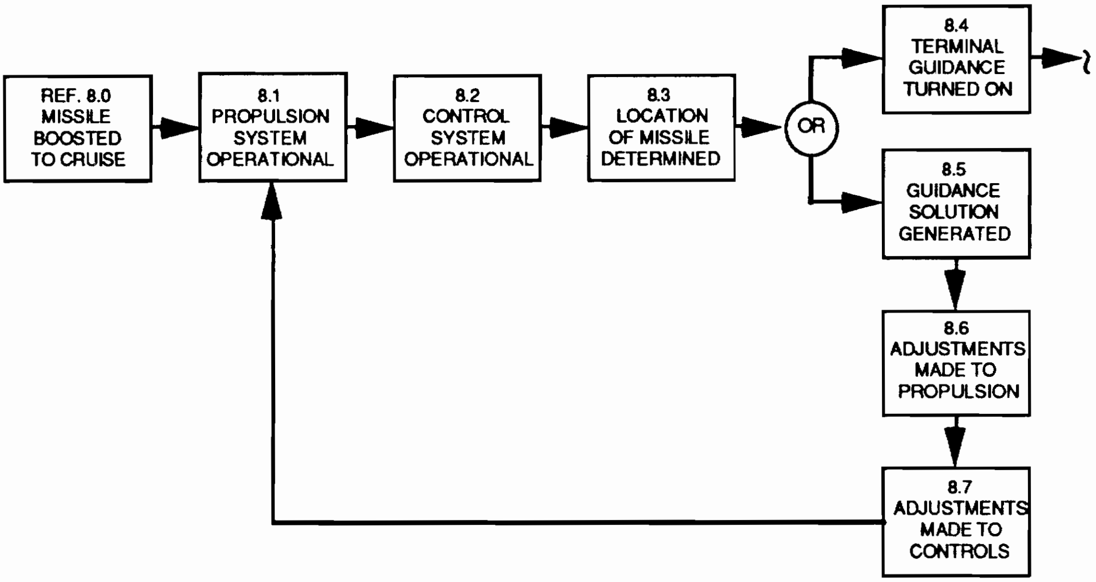


Figure 5: Second Level Functional Flow - Missile Midcourse Flight

The ninth function in Figure 3 is "missile reaches sensor range." Missiles are usually launched outside of the range of on-board sensors. When the missile has reached a certain point, on-board systems replace the launch platform's systems for guidance and tracking. The propulsion, guidance and control systems must function properly up to this point. Depending on the missile system, the midpoint may be determined prior to launch, and the missile must identify when it reaches this point (fire and forget systems) or the launch platform guides the missile to this point and signals for the missile to turn on its terminal systems. The functional flow is shown in Figure 6. From a vulnerability perspective, damaging or disorienting these systems will disrupt this process.

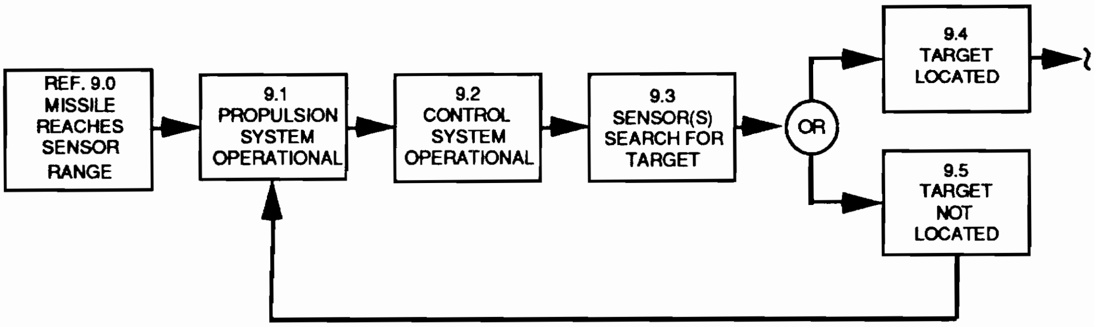


Figure 6: Second Level Functional Flow - Midcourse To Target Acquisition

The tenth function in Figure 3, "Target acquired/tracked" is shown in Figure 7. The on-board sensors system acquires the signature, and establishes and maintains a track of the target. The track is vital for directing the missile in reaching the target. As with the earlier function involving the launch platform, the vulnerability concerns involve deceiving or damaging the sensor systems. The difference here is that the systems are located on the missile itself, which is a smaller, faster and closer to the target.

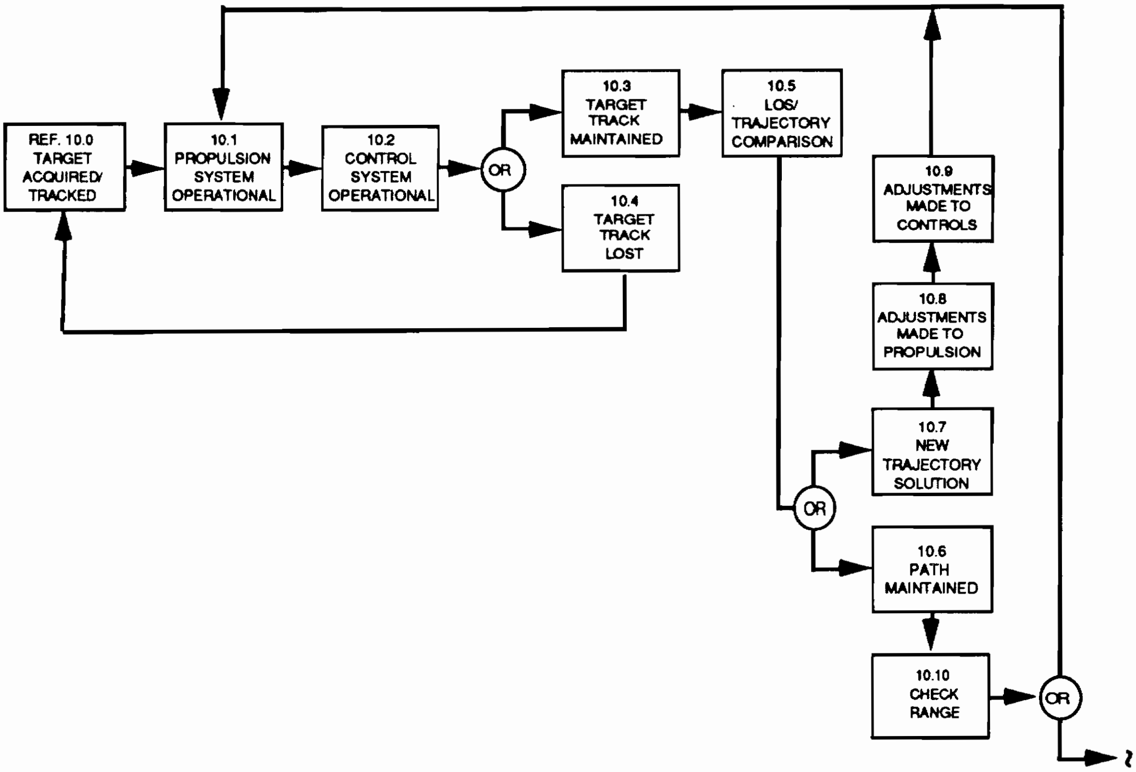


Figure 7: Second Level Functional Flow - Target Acquisition To Intercept

The missile flies to target, avoiding defenses, during the terminal phase. The control system follows instructions based on target tracking data. These instructions dictate the flight path that the missile must follow to reach the target. The vulnerability side must concern itself with making the control system ineffective or disrupting communication between the sensor, guidance, and control systems.

The final gross operational function, "Missile damages target," is shown in Figure 8. This function involves detonating a warhead, with the intent of disabling or sinking a ship. The warhead system must function properly, detonating at the right time and location. The vulnerability side must be concerned with limiting damage to their resources. This is difficult, as even if the warhead does not detonate, significant damage could be expected. However, large ships are capable of withstanding numerous hits at non-critical locations. Thus, the intention of the vulnerability team is to get the warhead to a) not detonate at all, b) detonate ineffectively ("fizz") or c) detonate at a location that does not cause critical damage. This may involve damaging the control system or warhead components.

At this point, the various subsystems can be identified for a cruise missile. They include propulsion, sensors/guidance, controls, and munitions. The structural system, which encloses all of the other systems could also be considered a system. Furthermore, we can determine which components are included in the propulsion and munitions systems. A third level functional analysis will help in identifying guidance and control components.

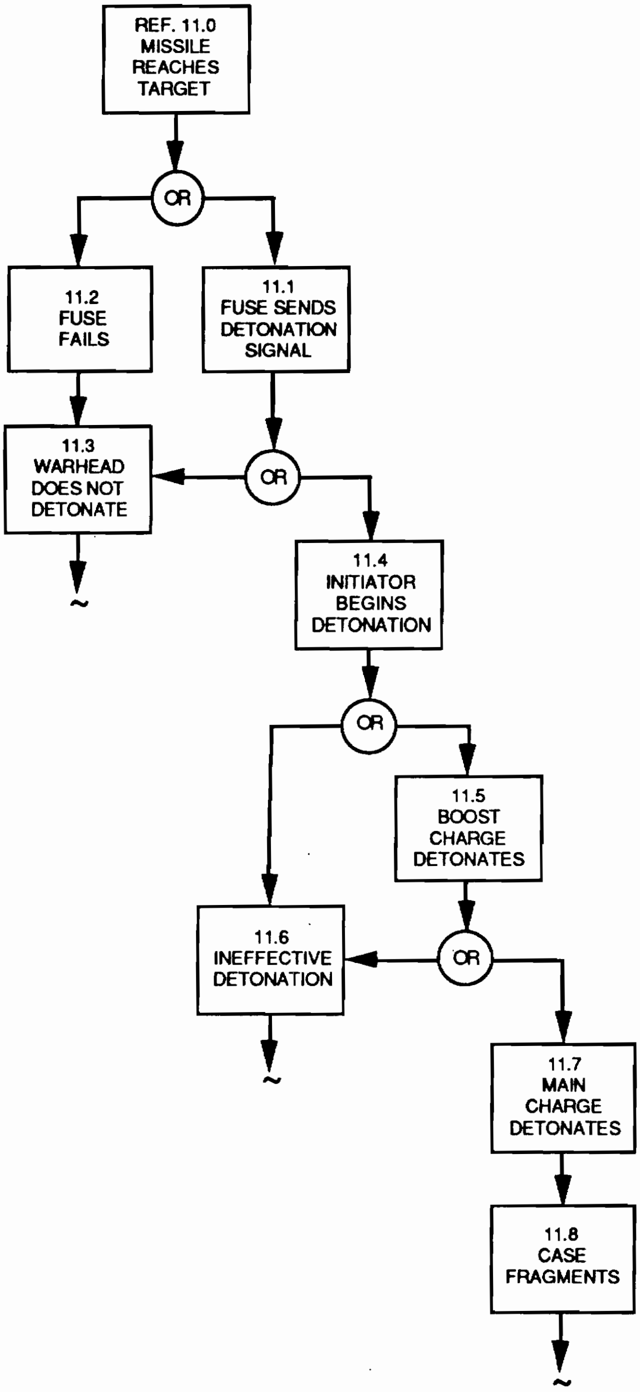


Figure 8: Second Level Functional Flow - Damage To Target

Figure 9 is similar to the second level diagram for initiating propulsion for a turbojet system. In this case, propulsion is merely being sustained. Although only Function 8.1 is referenced, the diagram could be referenced to Functions 9.1 or 10.1.

Figure 10 presents the functional flow for midcourse guidance. This involves determining where the missile is, and comparing that location to a predetermined value. Longitudinal, lateral and vertical accelerometers measure x -,y -, and z- direction accelerations, which are integrated to determine range, azimuth and altitude. The missile's location is continuously being monitored, with feedback being used to adjust the control system.

Figure 11 is similar to Figure 10, although this diagram represents the terminal guidance phase. Here, the missile's location is compared to the location of the target. The difference between the flight path and the line of sight to the target is identified as an error, which is sought to be corrected by the control system.

Figure 12 shows the functional flow of the tracking radar. In this case, the diagram represents a pulse doppler system. Although this diagram represents a third level of functions, it could be referenced to Function 8.4.4 as well.

At this point, the primary systems and components of a cruise missile have been shown.

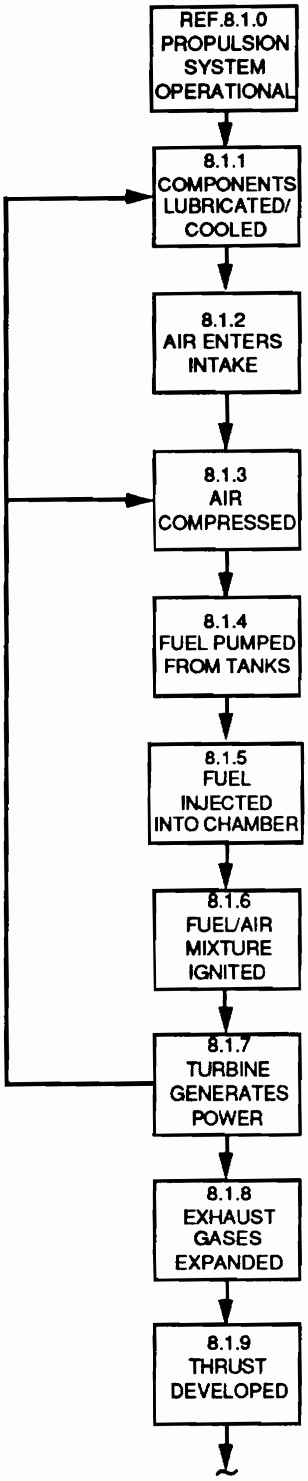


Figure 9: Third Level Functional Flow - Propulsion

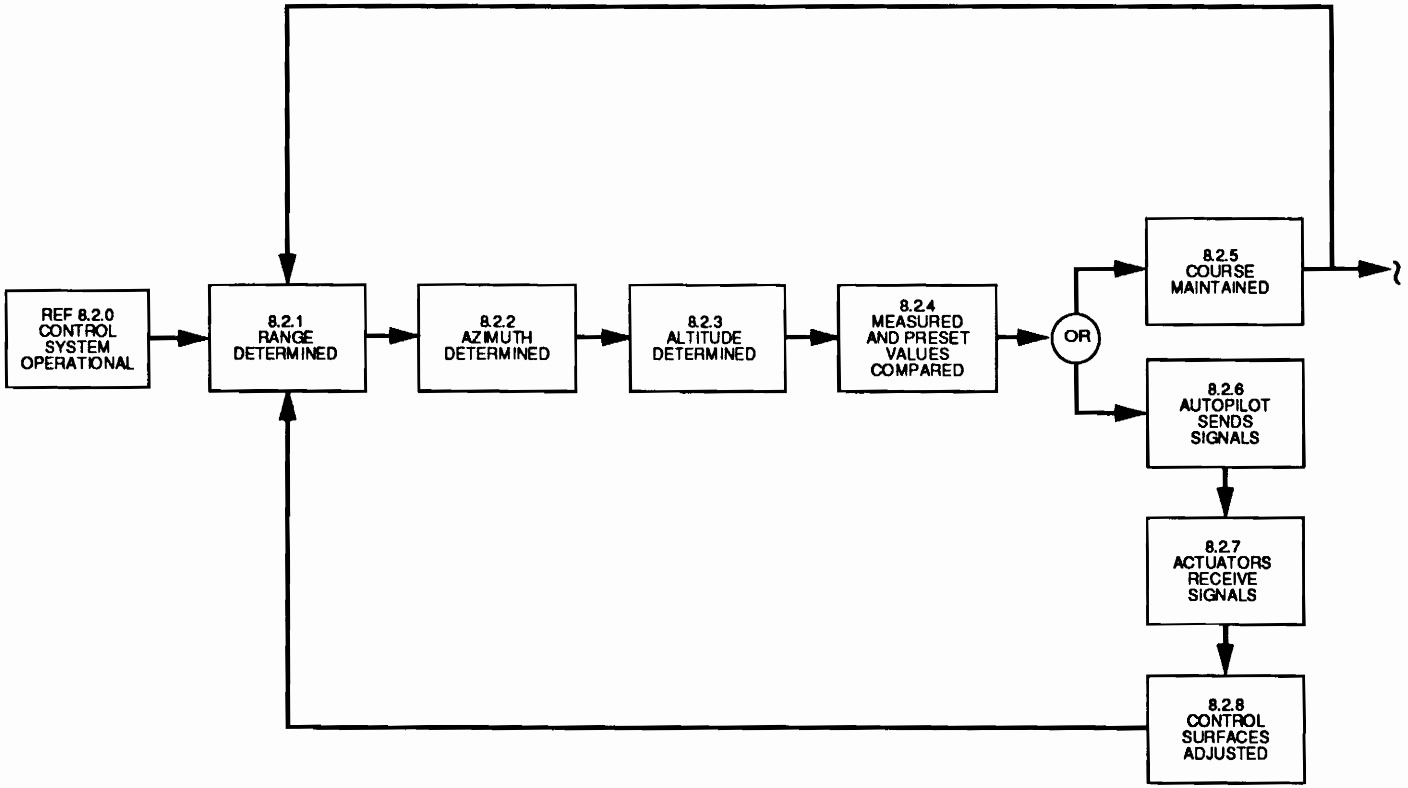


Figure 10: Third Level Functional Flow - Midcourse Guidance

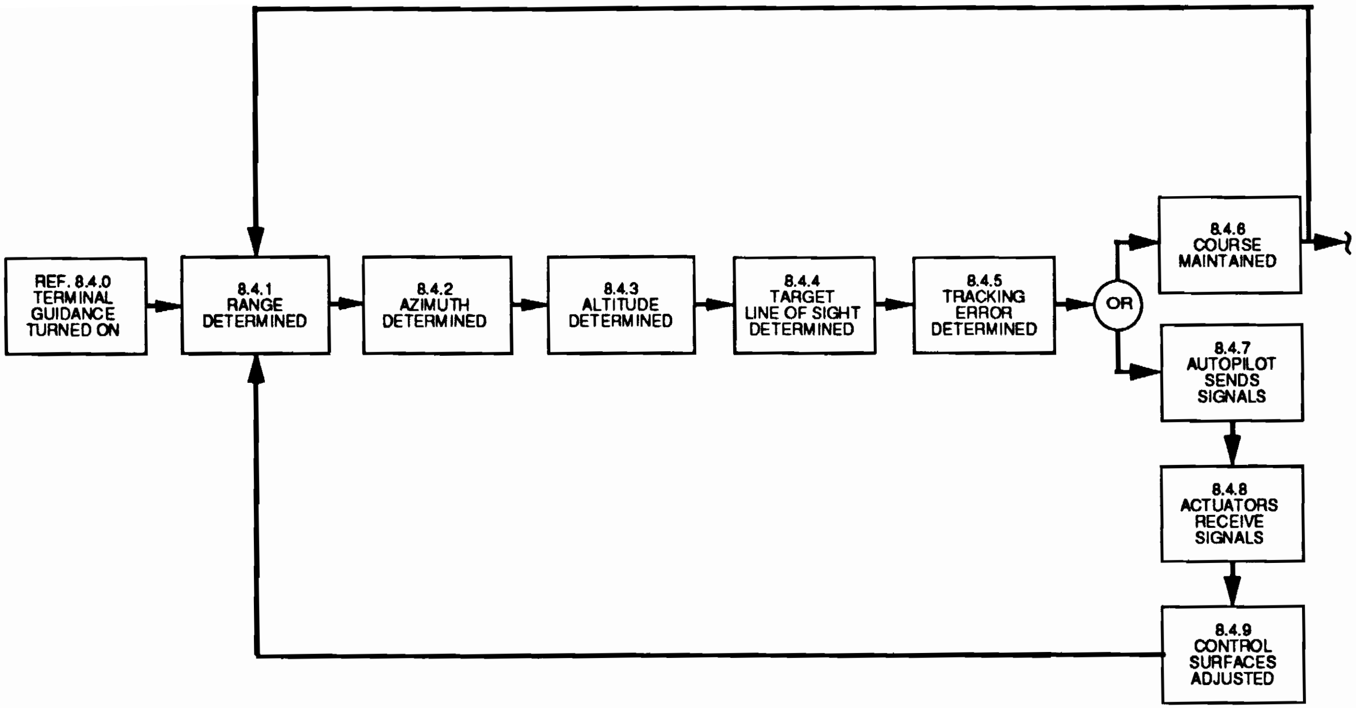


Figure 11: Third Level Functional Flow - Terminal Guidance

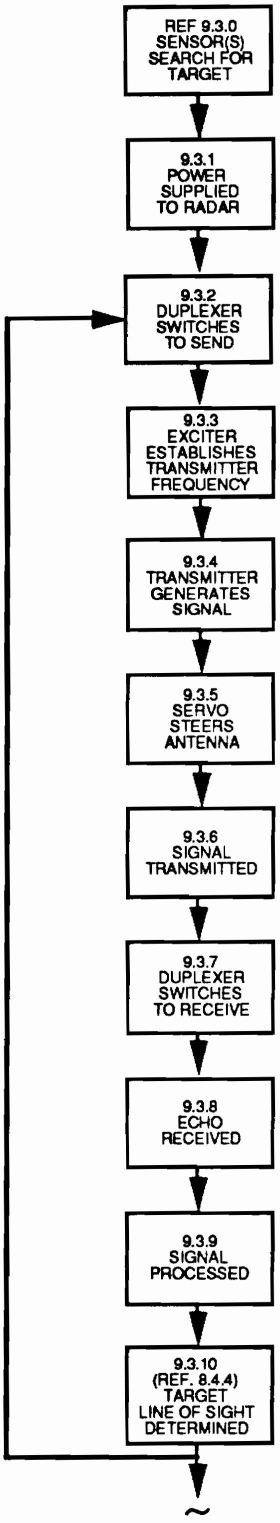


Figure 12: Third Level Functional Flow - Target Tracking

2.2 Allocation of Requirements

The allocation of requirements step of the functional analysis is the point in which actual requirements of the system are defined. In the case of a vulnerability analysis of cruise missiles, this step involves identifying the operational characteristics of both the cruise missile systems and the defensive systems that we are employing to defeat them.

2.2.1 Missile Characterization

The following missile parameters need to be considered: range, flight profile, speed, guidance characteristics, control characteristics, and munitions characteristics. If existing systems are an indication, there are wide ranges in most of these characteristics.

2.2.1.1 Range

Cruise missiles must be launched from ranges that protect the launching platform. However, once the missile is launched, most systems are "on their own." Longer ranges require larger powerplants, and/or increased fuel capacities. Guidance and control systems on missiles are generally less capable than those of the launch platform, and longer ranges tend to allow more things to go wrong with them. In general, missile range varies significantly, from less than 10 to over 1500 nautical miles.

2.2.1.2 Flight Profile

The intention here is for the missile to follow a flight path that is efficient, yet makes interception as difficult as possible. Depending on the launching platform, the missiles may be launched from zero altitude or high altitude. Following launch, they may climb to higher altitudes, dive to intermediate or low altitudes (sea skimming) or maintain the altitude of launch. Terminal flight profiles may consist of diving into the target, popping up and then diving into the top of the target, flying horizontally into the side of the target or flying over top of the target. In most cases, flight profiles are determined prior to launch and are system specific.

2.2.1.3 Speed

The objective is to have a missile reach a target as safely and quickly as possible. High speed targets give defenses less time to react, but at the price of maneuverability and detection. Slower missiles are able to creep up on a target and are relatively maneuverable, which makes them difficult to hit as well. As a result, both schools of thought figure into missile design, with speeds varying significantly, from high subsonic to mach 5.0 or above.

2.2.1.4 Guidance Characteristics

There are a number of ways in which a missile is guided to a target. There are three phases. Boost phase involves the guidance from launch to cruise, and is usually dictated by the launch platform. Midcourse guidance is responsible for getting the missile from the launch area to a range in which the terminal sensors are effective. The terminal guidance system must operate at a range that allows for an accurate identification of a target and gives the missile the opportunity to reach the target. On board sensors are limited by size and power constraints as dictated by the missile. Powerful sensors are larger, use more energy and add additional weight and size to a missile. These factors tend to degrade the dynamic performance of the missile.

2.2.1.5 Control Characteristics

Missiles can be highly maneuverable and slow, very fast and not very maneuverable, or a combination of these characteristics. Increasing speeds and maneuverability require stronger airframes, which lead to increased complexity and cost.

2.2.1.6 Munitions Characteristics

All missiles seek to damage a ship target, usually by penetration and warhead detonation to render that target inoperable. Most munitions systems feature some sort of explosive surrounded with a casing. Projectiles, blast, perforation and fire are common damage mechanisms. In extreme cases, nuclear and chemical means are used.

2.2.2 Warhead Characterization

As a means of defeating cruise missile systems, fragmenting warheads delivered by surface-to-air missiles are considered. Important parameters considered include fragment weight, shape and velocity distributions.

Actual characteristics of surface-to-air warheads are classified. In general, however, they operate by the same principles, albeit in a smaller way, as the systems addressed in Section 1.1.1.5. In anti-air systems, fragment sizes range from less than 1 grain (1/7000lb) to greater than 1000 grains (0.14lb). Fragments could be preformed in the shape of rods or cubes, or randomly shaped. Preformed fragments are usually all constant in size, while size distributions of random fragments vary. Fragment velocities vary, and in some cases, velocities greater than 15,000 ft/sec are possible.

2.3 Trade Off and Optimization

The trade off and optimization phase of functional analysis presents the means in which the requirements are met. At this point, the actual systems and their components are identified. Existing, or postulated, systems are being analyzed, and the design characteristics are set by outside considerations. To analyze a generic missile system, the characteristics should be based on existing systems.

Table 1 presents a listing of the most prevalent systems currently in service. System and performance characteristics are listed, based on information found in *Jane's Naval Weapons Systems*, *Jane's Air Launched Weapons*, and *The Naval Institute Guides to World Naval Weapons Systems* and *The Soviet Navy*. Flight profiles and control characteristics are not presented here, due to the fact that they are not usually available in open literature.

This table does not give any indication of the probability of encountering a given system. Thus, some systems that are produced by, and/or exported to, potentially hostile nations (SS-N-22, SS-N-2, Exocet, Otomat) would carry more weight. Likewise, some systems (SS-N-7, AS-7) have not been produced or exported in large numbers, or are nearing obsolescence, and will carry less weight. A U.S. missile, Harpoon, is included as a potential threat as it has been extensively exported.

Table 1. Cruise Missile Systems Currently In Use

ANTI-SHIP CRUISE MISSILES

Name (origin)	Launch Platform(s)	Length m(ft)	Guidance	Maximum Range km (nm)	Propulsion	Cruise Speed mach	Warhead
Harpoon (USA)	ship,air,sub	3.8 (12.5)	inertial,active radar	240 (130)	turbojet	0.9	SAP
Exocet (France)	ship,air,sub	5.8 (19.0)	inertial, active radar	50 (27)	solid rocket	0.9	SAP
Silkworm (PRC)	ship,land	7.4 (24.1)	active radar	100 (54)	turbojet	0.9	HE
C801/802 (PRC)	ship	5.8 (19.0)	inertial, active radar	40 (22)	solid rocket/turbojet	0.9	SAP
C-101 (PRC)	ship,land, air	6.5 (21.3)	inertial, active radar	45 (24)	ramjet	2.0	SAP
C-201 (PRC)	ship,land	7.4 (24.1)	active radar	150 (80)	turbojet	0.9	SAP
ANS (France)	ship,air,sub	5.7 (18.7)	inertial, active radar	180 (97)	rocket-ramjet	2.5	SAP
Otomat (Italy)	ship,land	4.6 (15.1)	inertial, active radar	160 (86)	turbojet	0.9	HE
SS-N-2 Styx (Russia)	ship,land	5.8 (19,0)	active radar	85 (46)	liquid rocket/turbojet	0.9	HE
SS-N-9 Siren (Russia)	ship,sub	8.8 (29.0)	inertial, active radar	111 (60)	solid rocket	0.9	nuclear,HE
SS-N-12 Sandbox (Russia)	ship,sub	11.7 (38.4)	inertial, active radar	550 (296)	turbojet	1.7	nuclear,HE
SS-N-7 Starbright (Russia)	ship,sub	6.5 (21.3)	active radar	64 (35)	solid rocket	0.9	nuclear,HE
SS-N-19 Shipwreck (Russia)	ship,sub	10.0 (32.8)	inertial, active radar	550 (296)	turbojet	1.6	nuclear,HE
SS-N-22 Sunburn (Russia)	ship	9.4 (30.7)	inertial, active radar	90 (48)	solid rocket	2.0	nuclear, HE
SS-N-25 (Russia)	ship	3.8 (12.4)	inertial, active radar	130 (70)	turbojet	0.9	SAP
Kormoran (Germany)	air	4.4 (14.4)	inertial, active radar	30 (16)	solid rocket	0.9	HE/projectiles
AS-4 Kitchen (Russia)	air	11.3 (37.1)	inertial, active radar	400 (215)	liquid rocket	2.5-3.5	nuclear,HE
AS-5 Kelt (Russia)	air	8.5(27.8)	inertial, active radar	326 (175)	liquid rocket	0.9-1.2	HE
AS-6 Kingfish (Russia)	air	10.5 (34.5)	inertial, active radar	300 (162)	turbojet?	2.5-3.5	nuclear, HE
AS-9 Kyle (Russia)	air	6.0 (19.7)	passive radar	90 (49)	liquid rocket	3.0	HE
AS-11 Kilter (Russia)	air	4.8 (15.7)	inertial, passive radar	70 (38)	solid rocket	4.0	HE blast/fragment
AS-12 Kegler (Russia)	air	4.2 (13.8)	inertial, passive radar	25 (13.5)	solid rocket	1.0	HE blast/fragment
AS-13 Kingbolt (Russia)	air	5.1 (16.7)	TV-command	90 (48.5)	solid rocket	0.8	HE
AS-15 Kent (Russia)	air, land	7.1 (23.3)	inertial, TERCOM	3000 (1617)	turbofan	0.8	nuclear, HE
AS-16 Kickback (Russia)	air	4.8 (15.7)	inertial, active radar	150 (80)	solid rocket	5.0	nuclear, HE
AS-17 Krypton (Russia)	air	4.7 (15.4)	inertial, active radar	50 (27)	solid rocket/ramjet	3.0	HE blast/fragment

Based on this table, certain trends are seen in characteristics. These trends are used to establish the characteristics for a generic cruise missile system to be analyzed in this study. The characteristics for this missile, designated Viper, are presented in Table 2.

Table 2. Characteristics Of A Generic Cruise Missile System

Name	SS-N-27/AS-20 Viper
Country of Origin	Russia
IOC	1997
Postulated Users	expected to be exported
Launch Platforms	SS-N-27: box launched: Kuznetsov (8 rounds) Slava (8), Neustrashimyy (4) tube launched: Akula (8), Sierra (8) AS-20: Tu-22M Backfire (8), Tu-160 Blackjack (12) Su-24 Fencer (2)
Length	4.06 m (160")
Diameter	body: 0.39 m (15.5") span: 0.96 m (37.6")
Guidance	midcourse : inertial terminal: active Pulse Doppler radar
Controls	cruciform fins, electric driven
Speed	max : Mach 0.8 at sea level
Range	100 km (60 nm)
Propulsion	turbojet
Flight Profile	sea-skimmer, possible pop-up maneuever
Warhead	semi-armor piercing, HE/fragmentation explosive weight 200 kg (440 lb)

Origin: Russia is chosen as the producer, due to the fact that Russian industry has the most substantial history in designing and producing cruise missiles. In recent years, this experience has been accompanied by an increasingly aggressive attempt to export these systems.

Launch Platform: Most common systems are capable of being launched from a variety of platforms. In the case of the Viper, it is capable of being carried in box launchers, by medium to large surface ships, on underwing pylons of ground attack aircraft, in the internal weapons bays of medium bombers, and the torpedo tubes of attack submarines.

Dimensions: The missile should be capable of fitting onto the pylons of an attack aircraft. The diameter is dictated by the fact that the missile may be launched from canisters or torpedo tubes. Standard Russian torpedo tubes are 53 cm (20.9") in diameter.

Propulsion: Turbojets allow for longer ranges, and are more flexible. Solid rockets may be used by more systems in Table 1, but turbojets allow for a better presentation of vulnerability principles.

Speed: Most turbojets travel in the high subsonic range. This speed is high enough to make detection and interception difficult. Subsonic speed also allows for the airframe and intake to be relatively simple in design.

Guidance system: Most systems in Table 1 use a form of inertial guidance and terminal active radar. Pulse-Doppler radars are generally more effective than pulsed systems.

Control System: Unclassified sources do not identify the internal structure of most missiles. Usually, hydraulic systems or electric motors are used to adjust the attitude of the control fins. Hydraulic systems require a set of pumps, reservoirs and fluid-filled lines. Electric systems are less complicated, with motors and sets of gears being used to rotate shafts that are attached to the fins. Both types of systems are equally effective. Thus, the decision to include an electric system in the Viper was arbitrary. The fin configuration is similar to the arrangement on Harpoon, SS-N-25, or Exocet. This allows for high maneuverability at high subsonic speed.

Munitions: The Viper is fitted with a semi-armor piercing warhead because the more common systems use them. As shown in Table 1, many Russian systems have nuclear options. It is extremely likely that export versions will not have this option.

To defeat the Viper, a naturally fragmenting warhead was chosen. Fragments were chosen as being cube-shaped, with sizes varying from 15 grains to 1000 grains. Velocities vary from 3000 ft/sec to 15,000 ft/sec. This selection represents existing warheads and allows for a more general representation of the Viper's vulnerability.

2.4 Conclusion

Functional Analysis has been used to determine which systems and components need to be addressed from a vulnerability standpoint. To demonstrate this point, the characteristics of a generic cruise missile, and a means to defeat it, have been defined. These are based on systems that are currently in use. However, it is expected that these systems will remain viable for the foreseeable future.

3.0 Failure Analysis

Examining the ways in which a missile system can fail is crucial to determining its vulnerability . There are two ways that system failure can be viewed. In the first case, the failure of individual components can be traced up to the ultimate effect on the system as a whole. Alternately, the overall effect (usually "mission failure") could serve as the starting point. Subsequent steps involve identifying the cause and effect relations that lead up to that point. Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) are used, respectively, for each of these approaches.

3.1 Failure Modes and Effectiveness Analysis (FMEA)

The FMEA identifies the relationship between each possible type of individual component or subsystem failure mode and performance of essential functions. The FMEA takes a bottom-up approach by identifying all possible failure modes of a component or subsystem (as identified by functional analysis) and determines the effects of each failure mode upon the capability to perform its functions. Typical failure modes include premature operation, failure to operate, failure to cease operation, failure during operation and degraded operation.

In the case of a cruise missile, the FMEA specifies the various ways in which the target can fail to maintain controlled flight or fail to perform its mission. Loss of, or at least serious degradation of, structural integrity, lift, power, control, or mission essential equipment constitute the failure modes.

The FMEA for the Viper, for a mission kill is presented in Table 3. The FMEA takes into account the fact the missile is being intercepted in the later stages of its flight profile. The warhead is armed and the on-board radar is being used for guidance. These conditions reflect the fact that the threats used against the missile, fragments from a surface-to-air missile, are being launched from the missile's intended target.

Kill levels denote the level of performance degradation for the system. For cruise missiles, two attrition kill levels, mission and recognizable, are usually considered. Mission kill, the less severe level, is concerned with preventing the missile from completing its mission. Recognizable kill involves identifying missile destruction within a very short (1-2 second) time frame.

Table 3. Failure Modes And Effects Analysis For A Cruise Missile System (page 1 of 7)

TARGET: VIPER - FMEA FOR MISSION KILL

SYSTEM	COMPONENT	DAMAGE	FAILURE EFFECT	SYSTEM RESPONSE	CRITICALITY	MISSILE RESPONSE
Propulsion	1500 Air Inlet Duct	Perforation	Fuel Ingestion	Flameout, Thrust lost within 5 sec	3(1)	Decreased range; Missile may miss target
Propulsion	1040 Front Bearing 1050 1160	Penetration	Loss of lubrication, Loss of rotor shaft stability	Internal engine damage Thrust lost within 1 min	3(7)	Decreased range; Missile may miss target
Propulsion	1170 Oil Seal Ring	Penetration	Loss of lubrication	Internal engine damage Thrust lost within 1 min	3(7)	Decreased range; Missile may miss target
Propulsion	1060 Front Mount	Fracture	Loss of rotor shaft stability	Internal engine damage Thrust lost within 1 min	3(7)	Decreased range; Missile may miss target
Propulsion	1150 Oil Pump Assy.	Penetration	Loss of lubrication	Internal engine damage Thrust lost within 1 min	3(7)	Decreased range; Missile may miss target
Propulsion	1190 Compressor Rotor Blades	Fracture/ Breakage	Foreign objects in engine compartment	Internal engine damage Thrust lost within 10 sec	3(2)	Decreased range; Missile may miss target
Propulsion	1220 Combustor Chamber	Perforation	Disruption of combustion	Internal engine damage Thrust lost within 5 sec	3(1)	Decreased range; Missile may miss target
Propulsion	1340 Fuel Lines 1390 1400 1440 1450 1460	Puncture	Loss of pressure, fuel flow to combustor chamber	Flameout, Thrust lost within 10 sec	3(2)	Decreased range; Missile may miss target
Propulsion	1350 Fuel Chamber	Penetrate	Loss of pressure, fuel flow to combustor chamber	Flameout, Thrust lost within 10 sec	3(2)	Decreased range; Missile may miss target

Table 3. Failure Modes And Effects Analysis For A Cruise Missile System (page 2 of 7)

SYSTEM	COMPONENT	DAMAGE	FAILURE EFFECT	SYSTEM RESPONSE	CRITICALITY	MISSILE RESPONSE
Propulsion	1410 Fuel Controls 1420	Penetration	Loss of regular fuel flow to combustor chamber	Flameout, Thrust lost within 10 sec	3(2)	Decreased range; Missile may miss target
Propulsion	1470 Rear Bearing	Penetration	Loss of rotor shaft stability	Internal engine damage Thrust lost within 1 min	3(7)	Decreased range; Missile may miss target
Propulsion	4xxx Fuel	Penetration	Loss of fuel within:	Flameout,Loss of thrust		Decreased range;
	4100		" 2.00 min	"	3(15)	Missile may miss target
	4100		" 2.25 min	"	3(17)	"
	4120		" 2.50 min	"	3(20)	"
	4130		" 2.75 min	"	3(22)	"
	4140		" 3.00 min	"	3(25)	"
	4150		" 3.25 min	"	3(27)	"
	4160		" 3.50 min	"	3(29)	"
	4170		" 3.75 min	"	3(32)	"
	4180		Fuel Ingestion	"	3(2)	"
	4190		"	"	3(2)	"
	4200		"	"	3(2)	"
	4210		"	"	3(2)	"
	4220		"	"	3(2)	"
	4230		"	"	3(2)	"
	4240		"	"	3(2)	"
	4250		"	"	3(2)	"
Structure	0410 Upper Port Wing	Perforation	Wing loss, or severe damage	Loss of lift, stability	4	Degraded Flight
Structure	0420 Upper Starboard Wing	Perforation	Wing loss, or severe damage	Loss of lift, stability	4	Degraded Flight

Table 3. Failure Modes And Effects Analysis For A Cruise Missile System (page 3 of 7)

SYSTEM	COMPONENT	DAMAGE	FAILURE EFFECT	SYSTEM RESPONSE	CRITICALITY	MISSILE RESPONSE
Structure	0430 Lower Port Wing	Perforation	Wing loss, or severe damage	Loss of lift, stability	4	Degraded Flight
Structure	0440 Lower Starboard Wing	Perforation	Wing loss, or severe damage	Loss of lift, stability	4	Degraded Flight
Control	3010 Upper Port Fin	Perforation	Fin loss, or severe damage	Loss of stability	4	Degraded flight
Control	3020 Upper Starboard Fin	Perforation	Fin loss, or severe damage	Loss of stability	4	Degraded flight
Control	3030 Lower Port Fin	Perforation	Fin loss, or severe damage	Loss of stability	4	Degraded flight
Control	3040 Lower Starboard Fin	Perforation	Fin loss, or severe damage	Loss of stability	4	Degraded flight
Control	3110 Upper Port Fin Shaft	Shear	Fin loss	Loss of stability	4	Degraded flight
Control	3120 Upper Starboard Fin Shaft	Shear	Fin loss	Loss of stability	4	Degraded flight
Control	3130 Lower Port Fin Shaft	Shear	Fin loss	Loss of stability	4	Degraded flight
Control	3140 Lower Starboard Fin Shaft	Shear	Fin loss	Loss of stability	4	Degraded flight
Control	3210 Upper Port Actuator	Penetration	Damage to internal mechanism	Control fin locks	4	Degraded flight

Table 3. Failure Modes And Effects Analysis For A Cruise Missile System (page 4 of 7)

SYSTEM	COMPONENT	DAMAGE	FAILURE EFFECT	SYSTEM RESPONSE	CRITICALITY	MISSILE RESPONSE
Control	3220 Upper Starboard Actuator	Penetration	Damage to internal mechanism	Control fin locks	4	Degraded flight
Control	3230 Lower Port Actuator	Penetration	Damage to internal mechanism	Control fin locks	4	Degraded flight
Control	3240 Lower Starboard Actuator	Penetration	Damage to internal mechanism	Control fin locks	4	Degraded flight
Control	3310 Upper Port Actuator Wire	Severance	Loss of signal	Control fin locks	4	Degraded flight
Control	3320 Upper Starboard Actuator Wire	Severance	Loss of signal	Control fin locks	4	Degraded flight
Control	3330 Lower Port Actuator Wire	Severance	Loss of signal	Control fin locks	4	Degraded flight
Control	3340 Lower Starboard Actuator Wire	Severance	Loss of signal	Control fin locks	4	Degraded flight
Control	3530 Wire From Autopilot To Actuators	Severance	Loss of signal	Loss of pitch/roll/ yaw control	3(2)	Loss of control; Missile may miss target
Guidance	6110 Longitudinal Accelerometer	Penetration	Damage to instruments; No measurement of missile range	Inaccurate guidance solution generated	3(3)	Missile may miss target
Guidance	6120 Lateral Accelerometer	Penetration	Damage to instruments; No measurement of missile azimuth	Inaccurate guidance solution generated	3(3)	Missile may miss target

Table 3. Failure Modes And Effects Analysis For A Cruise Missile System (page 5 of 7)

SYSTEM	COMPONENT	DAMAGE	FAILURE EFFECT	SYSTEM RESPONSE	CRITICALITY	MISSILE RESPONSE
Guidance	6130 Vertical Accelerometer	Penetration	Damage to instruments; No measurement of missile altitude	Inaccurate guidance solution generated	3(3)	Missile may miss target
Guidance	6150 Wire,From Accelerometers To Computer	Severance	Missile range, azimuth, elevation data not sent	Inaccurate guidance solution generated	3(3)	Missile may miss target
Guidance	6100 Gyros Block	Penetration	Jamming of mechanism; Reference signal goes to zero	Inaccurate guidance solution generated	3(3)	Missile may miss target
Guidance	6550 Autopilot	Penetration	Damage to circuits; No control signal	Loss of control guidance	3(2)	Missile may miss target
Guidance	6560 Wire, Power To Autopilot	Severance	No power supplied to system; Control signal not generated	Loss of control guidance	3(2)	Missile may miss target
Guidance	6500 Flight Computer	Penetration	Damage to circuits; No guidance solution	Loss of control guidance	3(2)	Missile may miss target
Guidance	6510 Wire, Power To Flight Computer	Severance	No power supplied to system; Guidance solution not generated	Loss of control guidance	3(2)	Missile may miss target
Guidance	6610 Radar Antenna	Penetration	Damage to transmitting/ receiving dish	Degradation, or loss, of missile tracking signal	3(2)	Loss of track; Missile may miss target
Guidance	6620 Radar Antenna Servo	Penetration	Jamming or breaking of mechanism	Loss of antenna drive system	3(2)	Loss of track; Missile may miss target

Table 3. Failure Modes And Effects Analysis For A Cruise Missile System (page 6 of 7)

SYSTEM	COMPONENT	DAMAGE	FAILURE EFFECT	SYSTEM RESPONSE	CRITICALITY	MISSILE RESPONSE
Guidance	6630 Radar Transmitter	Penetration	Damage to circuits; Radar signal not sent	No tracking signal sent	3(2)	Loss of track; Missile may miss target
Guidance	6640 Radar Duplexer	Penetration	Damage to switch; Locked in position, or short circuit	Tracking signal not sent, or locked in transmit or receive mode	3(2)	Loss of track; Missile may miss target
Guidance	6650 Radar Exciter	Penetration	Damage to circuits; Signal not generated, or short circuit	Tracking signal not sent	3(2)	Loss of track; Missile may miss target
Guidance	6660 Radar Data Processor	Penetration	Damage to circuits; Signal not evaluated, or short circuit	Target location not determined	3(2)	Loss of track; Missile may miss target
Guidance	6670 Wire, Power To Radar	Severance	No power supplied to system	Tracking signal not sent	3(2)	Loss of track; Missile may miss target
Guidance	6680 Wire, From Radar To Computer	Severance	No tracking data sent	Guidance solution not generated	3(2)	Missile may miss target
Electrical	8150 Distribution Block	Penetration	Damage to circuits; Loss of electric power	No power to onboard systems	2	Guidance, control systems fail;
Electrical	8100 Battery	Penetration	Damage to cells; Loss of electric power	No power to onboard systems	2	Guidance, control systems fail;
Munitions	5120 Warhead Initiator	Penetration	Residual energy may lead to detonation	Warhead detonates prematurely	1	Missile destroyed

Table 3. Failure Modes And Effects Analysis For A Cruise Missile System (page 7 of 7)

SYSTEM	COMPONENT	DAMAGE	FAILURE EFFECT	SYSTEM RESPONSE	CRITICALITY	MISSILE RESPONSE
Munitions	5130 Warhead Booster Charge	Penetration	Residual energy may lead to detonation	Warhead detonates prematurely	1	Missile destroyed
Munitions	5140 Warhead Main Charge	Penetration	Residual energy may lead to detonation	Warhead detonates prematurely	1	Missile destroyed
Munitions	5210 Contact/ 5220 Crush Fuses 5230 5240	Penetration	Fuses activated, completing circuit	Warhead detonates prematurely	1	Missile destroyed

Criticality Codes:

1 Catastrophic Failure: Missile is destroyed in flight, prior to completing mission.

2 Critical Failure: Missile performance is degraded beyond acceptable limits. Low probability (< 0.1) of completing mission.

3(x) Conditional Critical Failure: Critical failure occurs if missile is at least (x) nm from target. Minor Failure otherwise.

4 Major Failure: Missile performance is degraded significantly, but can be compensated for by other means.

5 Minor Failure: Missile performance is not degraded to the level in which mission could not be completed.

The probability of each damage mode effect occurring is equal to the product of the probability of a fragment hitting the component and the probability of that fragment damaging the component. The probability of the fragment hitting the component is dependent on fragment cloud density, fragment trajectory, and component size and location. Component damage probabilities (P_{dh}) give a measure of the amount of damage that a given component can withstand before being considered disabled. These probabilities are relative to fragment size and velocity. The vulnerability analysis (Section 4) accounts for these factors in determining the likelihood of component failure (expressed in terms of vulnerable areas).

Each critical component has a reliability (expressed as a probability) associated with it, and failure can be completely independent of damage mechanisms. Reliability values may vary significantly, and proper determination would require detailed knowledge of component design. A recommendation for future research involves taking into account the effects of component reliability in failure analysis with regards to vulnerability.

A potential drawback of the FMEA involves the fact that it only presents the effects of damaging individual components. In reality, many components are likely to be damaged to some degree. For this reason, the FMEA should not be considered as a complete measurement of a target's overall vulnerability.

In regards to failure modes for the propulsion system, cutting off the fuel flow or damaging the internal engine components defeats the system. Defeating the system is most likely to decrease the missile's range. However, if the missile is near its target when the propulsion system is defeated, it may be able to complete its mission.

As listed in the FMEA, failure modes for the structural system are limited to removal of the forward wings. Removal of one wing will affect the flight characteristics, yet the control system should be able to compensate. Removal of multiple wings, on the other hand, is likely to have significant effects on the missile's lift and stability characteristics. Damage to skin and structural members will adversely affect the missile's performance. Their exclusion from the FMEA, however, is due to the fact that damaging these components is likely to be a secondary effect to damaging less rugged components.

The control system failure modes involve removing fins, damaging components, or severing wires. As with the wings, disabling, or removing, one control surface merely degrades performance. Disabling multiple surfaces is likely to result in serious effects on the missile's flight worthiness. It is worth noting that severing only one wire (component #3530) can defeat the whole system.

Defeating the guidance system involves damaging components, cutting off the power supply, or cutting off the flow of tracking signals. In this case, all components are non-redundant; each component is responsible for specific contributions to system performance. Disabling one component is likely to bring the whole system down. This system must be defeated at least 2 nm from its target. Otherwise, the missile will continue its course and "glide" into its target.

The electrical system provides power to all of the other systems on board the missile. Thus, disabling the components in this system disables the other systems as well.

In order for the munitions system to be defeated, the warhead must be detonated at some distance from the target. For this to happen, the explosive charges must be provided with sufficient energy (from the penetrating fragments) to detonate, or the circuit that controls fusing must be closed prematurely. The circuit can be closed by accounting for the fact that the crush fuses are designed to operate by being destroyed (by hitting a hard surface on the target). Thus, hitting the fuses with a hard fragment should have similar effects.

3.2 Fault Tree Analysis (FTA)

Another way of evaluating the failure modes for the Viper is through fault tree analysis (FTA). Although this method is not as descriptive (on a component level) as the FMEA, redundancy and relations between components are more clearly defined. Fault tree analysis is a top down approach that starts by assuming an undesired event has occurred and then proceeds with a determination of which combination of preceding events could have caused it.

The fault tree analysis of the cruise missile begins with the objective of the vulnerability analyst: keep the missile from seriously damaging its target. The first level is shown in Figure 13. As can be seen, this fault/objective can be accomplished by defeating any of the major systems. In fact, with the exception of the warhead system, disabling the system will result in defeating the missile. In the case of the warhead, merely disabling the system may not be sufficient to prevent serious damage from occurring. Figures 14-16 expand the fault tree. In these cases, failures associated with the guidance, propulsion, control and warhead systems were evaluated. "Structural Breakup" refers to the fact that the missile is damaged to such a degree that it disintegrates.

As with the FMEA, the fault tree analysis accounts for damage events only, with probabilities of occurrence being determined in the vulnerability analysis (Section 4).

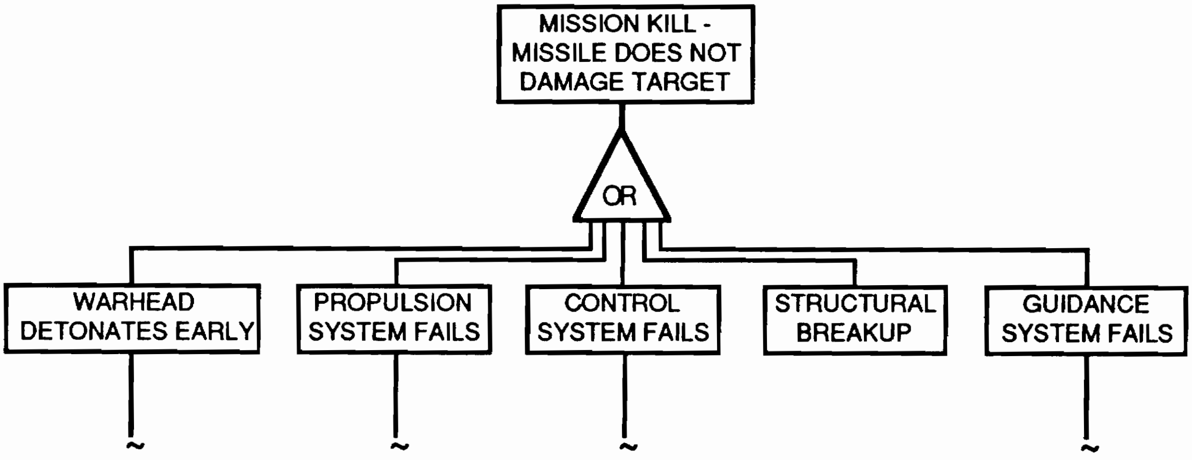


Figure 13: First Level Fault Tree For A Cruise Missile System

Figure 14 expands the first level fault tree by detailing the faults associated with the guidance system. This system is dependent on the transmission of signals between components. Disrupting communication between components will be sufficient to defeat this system. This can be done by damaging the components or severing the connections between components. Wiring is not generally redundant in missiles. All components related to this system require electrical power. Thus, disabling the power source, distributor or power lines will defeat the system (and most other systems as well).

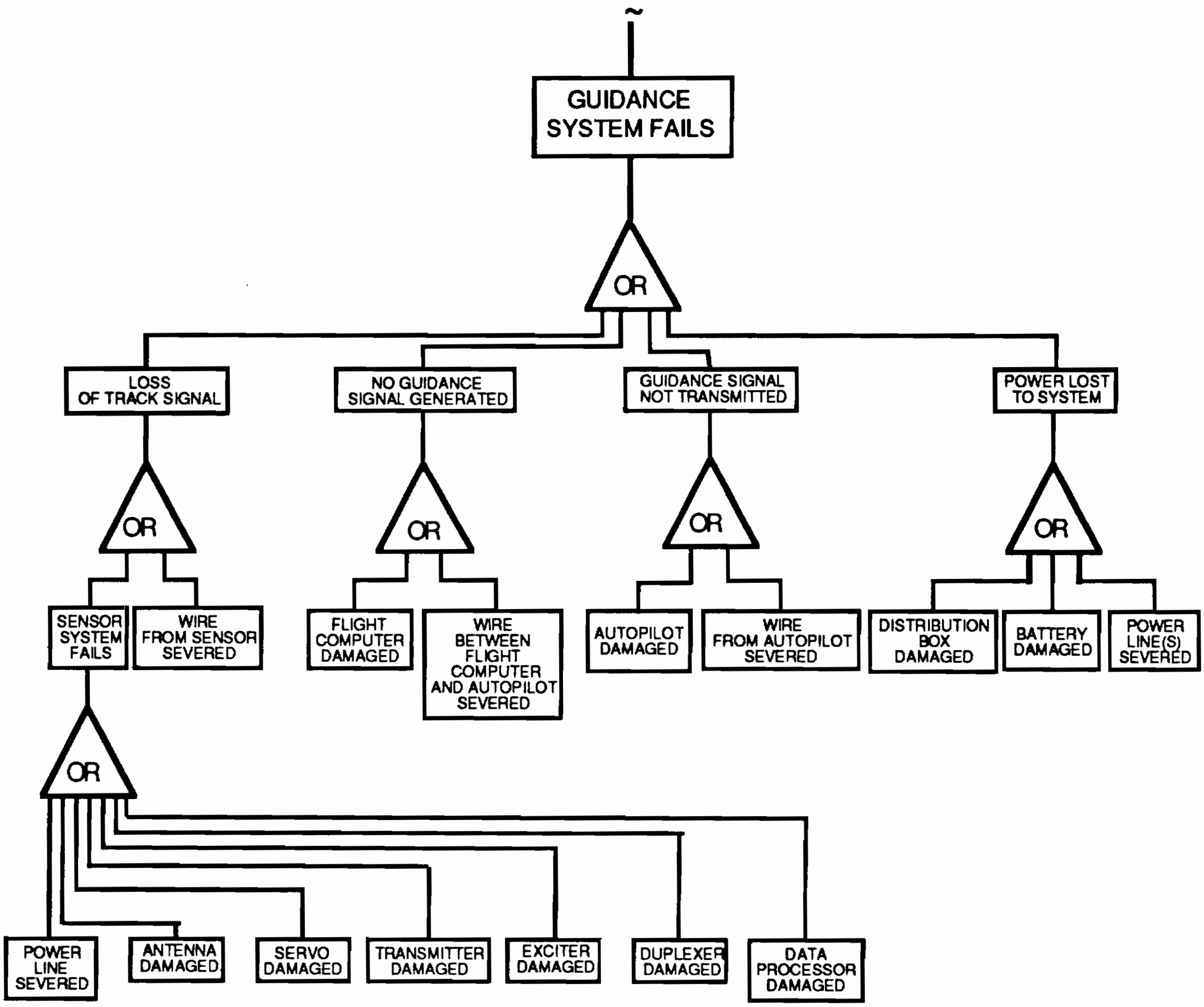


Figure 14. Fault Tree Analysis For A Cruise Missile Guidance System

The control system is closely linked to the guidance system. This association is shown by the inclusion of "guidance system fails" as an event in Figure 15. Again, electrical power is necessary for this system to operate. Depending on the missile, an electrical system failure will result in the control fins either becoming free-floating or locking in place. In the case here, locking is the response. Either way, the missile becomes unable to correct its attitude and departure from controlled flight results. Loss of one control surface degrades the performance of the missile, but this can usually be compensated for, and the missile is still able to maintain flight for a period of time. Loss of more than one fin, however cannot be compensated for. Fin loss can be defined as physical removal or disablement of the control mechanism. Physical removal comes about when a large fragment, or group of fragments, perforates the skin to a point in which the effective surface area becomes insignificant (usually about 25% removal). Also, if the shaft connecting the fin to the actuator is sheared, the fin may simply fall off. The control mechanism (consisting of motor and gears) is housed inside the actuator. Disabling this component, or cutting off the signal to it, has the same effect as an electrical failure.

The fault tree analysis of the propulsion system is shown in Figure 16. In this case, damaging components or disrupting the flow of fuel will result in a system failure. Fuel ingestion occurs when fuel is injected into the forward end of the engine. This is more likely to occur in the early stages of flight (when the tanks are more full). Even small holes in the fuel system are likely to result in a loss of pressure, and subsequently, flameout. Damaging the lubrication components is likely to result in the engine overheating and seizing up. The effects of this occurrence are not instantaneous, but loss of thrust could be expected in less than a minute in most cases.

Figure 17 details the faults associated with the warhead system. In this case, the warhead can be detonated prematurely by penetrating the case with a sufficient amount of residual energy to detonate the explosive charges inside, or by closing the fusing circuit by activating the contact/crush fuses.

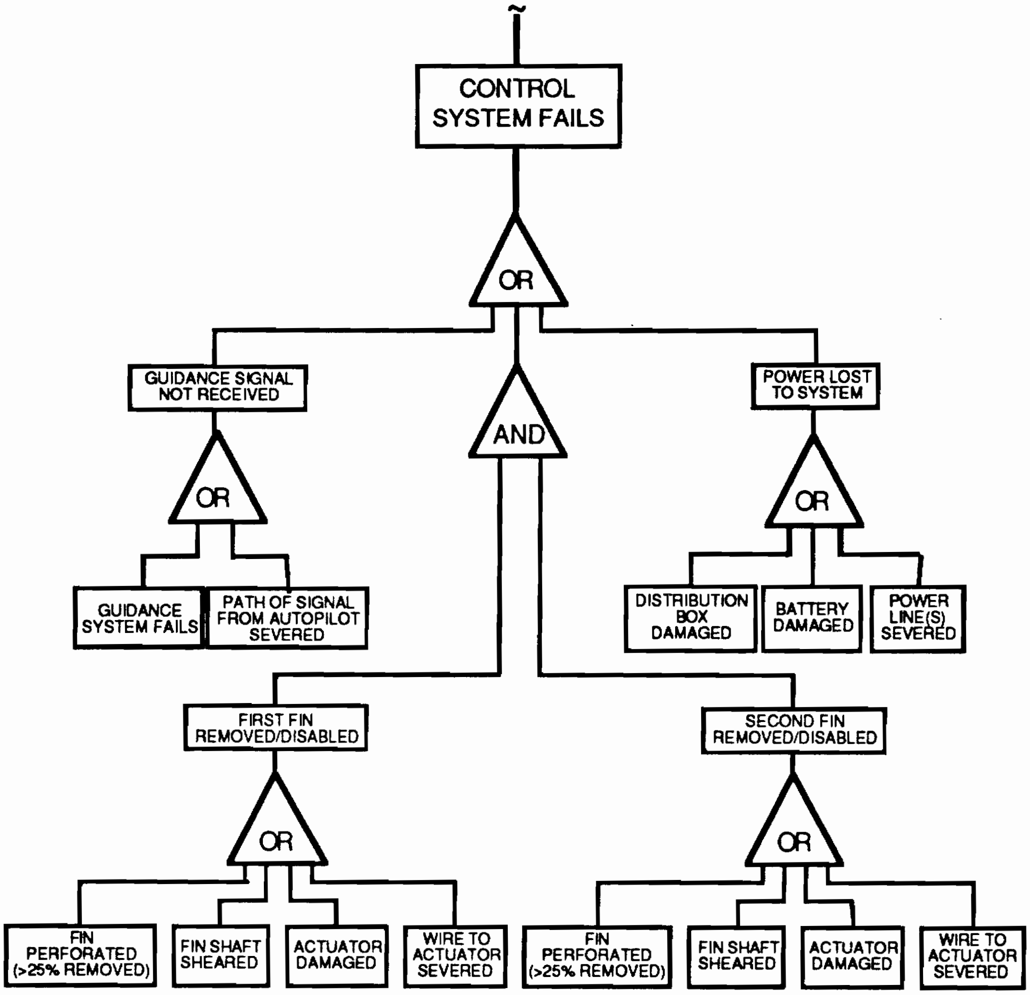


Figure 15. Fault Tree Analysis For A Cruise Missile Control System

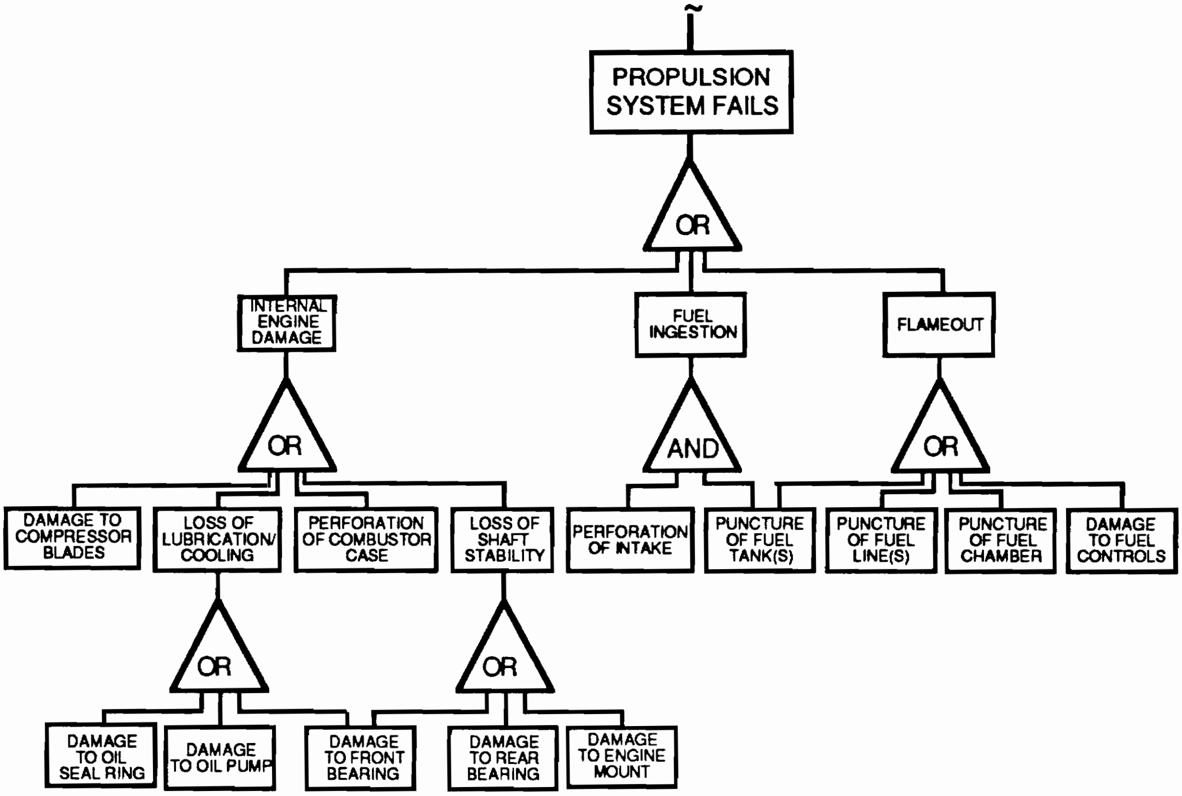


Figure 16. Fault Tree Analysis For A Cruise Missile Propulsion System

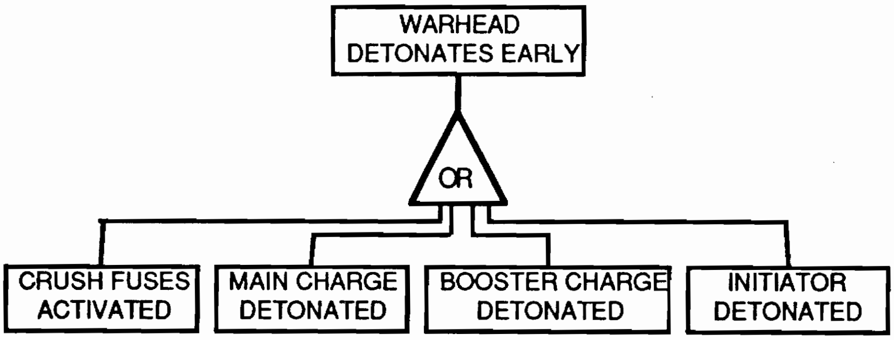


Figure 17. Fault Tree Analysis For A Cruise Missile Warhead System

3.3 Conclusion

By using Failure Analysis, the ways in which a cruise missile system can be defeated have been identified. The likelihood of these failures occurring has not been quantified; thus, the true measure of the vulnerability of the system has not been determined. To do this, a Vulnerability Analysis of the missile system can be conducted.

4.0 Vulnerability Analysis

4.1 Introduction

The functions associated with a cruise missile system have been determined. This has lead to an identification of the components included in the system. Fault Analysis has identified which components are critical to particular missile system operations. As a final step, the vulnerability assessment involves applying the physical, functional, and fault characteristics to determine the overall vulnerability of the system to hard kill mechanisms for a particular kill definition.

"Target Vulnerability" is defined as the inability of a system to withstand damage. Every system, and each component within that system, is vulnerable to a certain degree. Furthermore, the vulnerability of each component contributes to the vulnerability of the system.

Vulnerability assessments provide numerical values for quantifying the measures of vulnerability. These measures include the conditional probability that the cruise missile is killed given a random hit (Pkh). Another measure determines the vulnerable area (Av) of the missile. These measures apply to both individual components and the missile as a whole. The vulnerable area is defined as the product of the presented area in the plane normal to the approach direction (shotline), and the Pkh. On a component level, Pkh is essentially aspect independent, while Av is not. This method takes into account only whether a component is functioning or not; degraded performance is usually not considered.

All assessments take into account characteristics of the threat (the means of damaging the cruise missile) selected. These threats fall into the following categories: penetrating projectiles or fragments, internally detonating HE projectiles and external blast/fragmentation warheads.

Small-to-medium caliber gun launched projectiles may have internally detonating warheads. In this case, evaluation using parallel shotlines is not valid. Taking this into account, the actual presented area could be expanded and the results being applied to non-explosive methods. Another method is assuming that detonations occur at selected burstpoints. Each burstpoint is treated like a fragment, with the effects on nearby components being evaluated. This evaluation determines whether the component and, ultimately, the entire target is killed.

Externally detonating warheads feature blast fronts followed by fragments. Fragments usually cause the most damage, although incendiary particles and blast can contribute significantly as well. Thus, the vulnerability is analyzed in two steps. Vulnerability to blast is usually expressed as an envelope about the target where the detonation of a specific amount of explosive will result in a specified level of damage or kill to the target. Although the dimensions of this envelope are determined from blast considerations, there are fragment effects as well. Damage from blast is usually limited to airframe structural and control surfaces. Fragments from externally detonating warheads are usually uniformly ejected with divergent trajectories. Consequently, analysis using parallel shotlines, at least near the target, is not valid. At sufficient distance, however, assuming parallel shotlines gives results that are reasonably accurate.

A complete assessment takes into account the possibility of engaging the target at various azimuth and elevation angles. Also, any assessment should take into account vulnerability reduction concepts, such as redundancy, location, and shielding.

4.2 Computer Programs For Vulnerability Analysis

A number of computer programs have been developed for assessing vulnerability. They fall into three categories: shotline generators, vulnerable area routines, and internal burst programs. The first two methods are used to evaluate fragments and penetrators. The third method is used for internally detonating warheads. Lethality analysis, which involves endgame routines, utilizes the output from these programs.

Shotline generators are used to provide the data for determining vulnerable areas. Shotlines are obtained by superimposing a square grid over the surface area exposed at specific azimuth and elevation values. Parallel shotlines are then traced perpendicularly through each section of the grid. The program traces the path through the target, resulting in a list of components, voids and fluids encountered. FASTGEN is the currently accepted method of generating shotlines, with the results being stored in a line-of-sight (LOS) file. As a prerequisite to running FASTGEN, a geometric model of the target is developed. This model takes into account all components, describing them in plate or volume mode. The actual construction is as a series of panels (described as interconnected triangles), boxes, spheres, or cylinders.

A FASTGEN geometric model of the Viper (from an aspect of 45 degrees azimuth, 45 degrees elevation) is shown in Figures 18 and 19. Views of the propulsion, guidance and control systems are shown in Figures 20-22. A listing of all the components that are included in the model is shown in Table 4. Critical components are listed in italics.

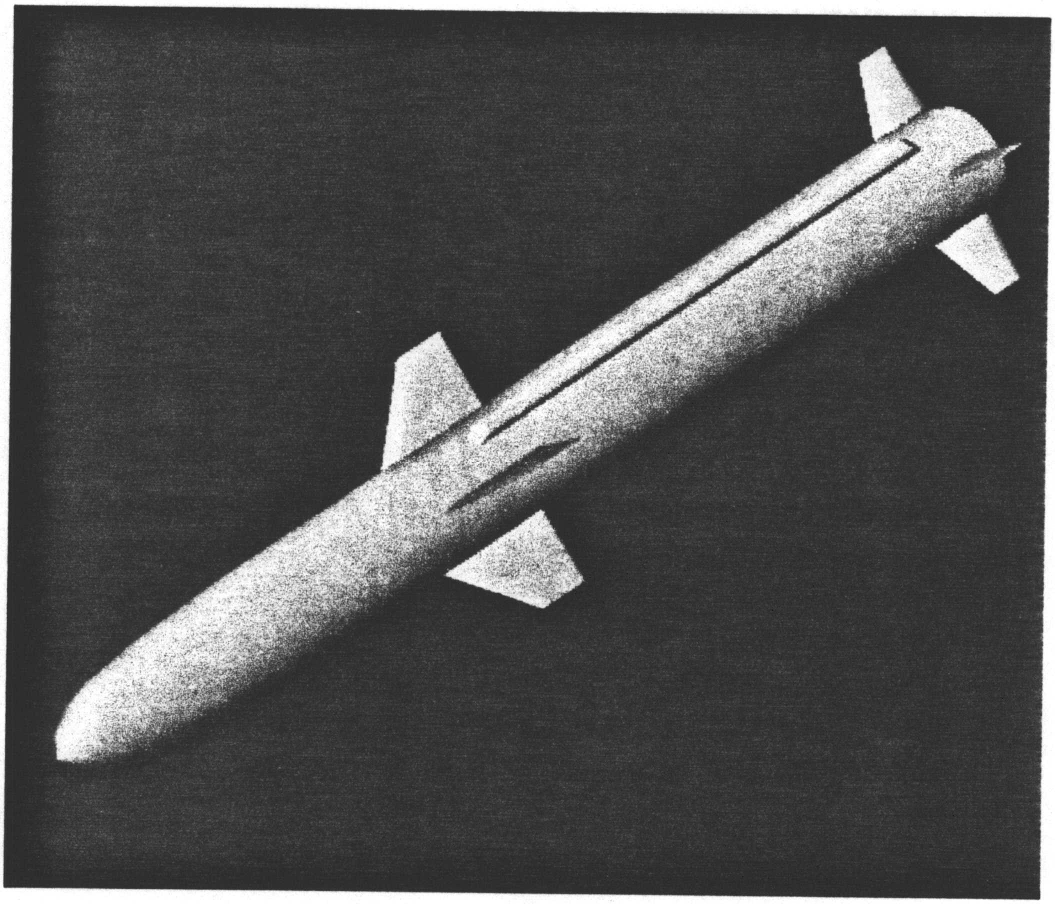


Figure 18: Viper Cruise Missile

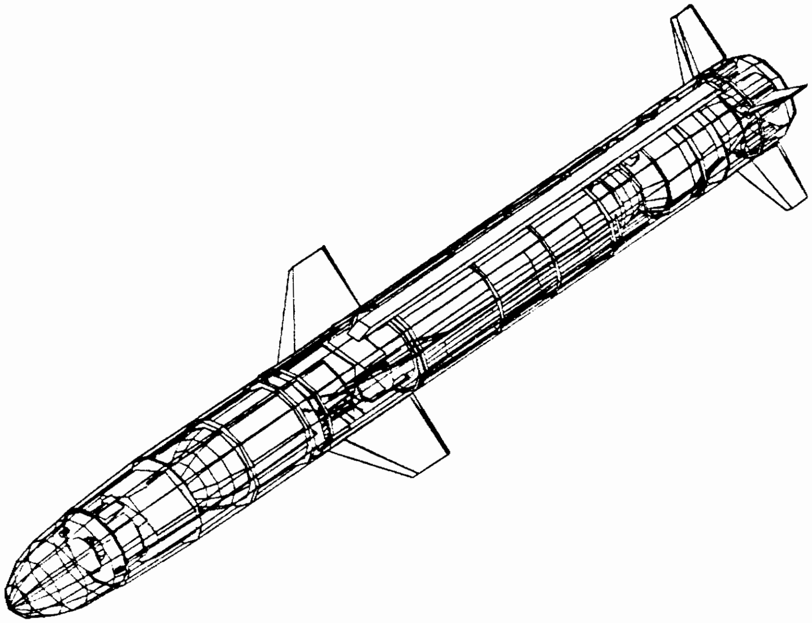


Figure 19: Wire Frame Of Viper Geometric Computer Model

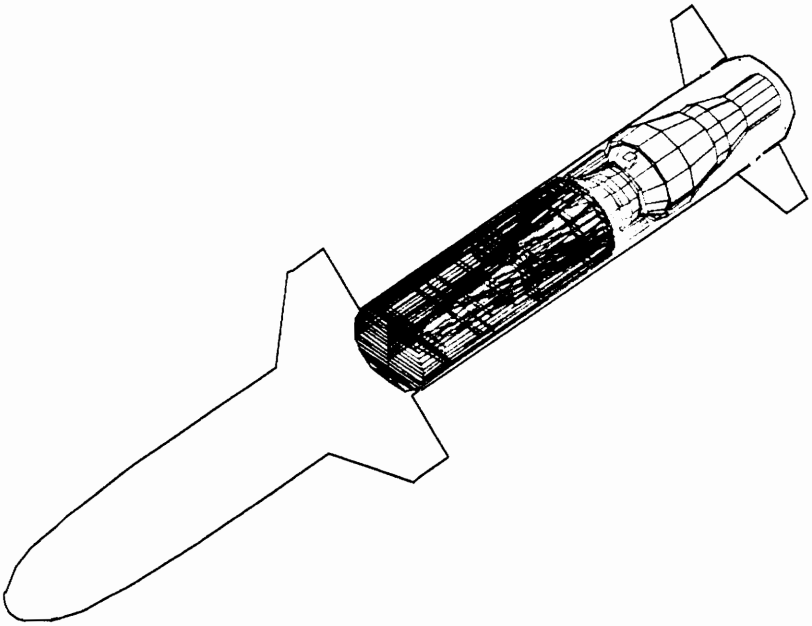


Figure 20: Viper Propulsion System

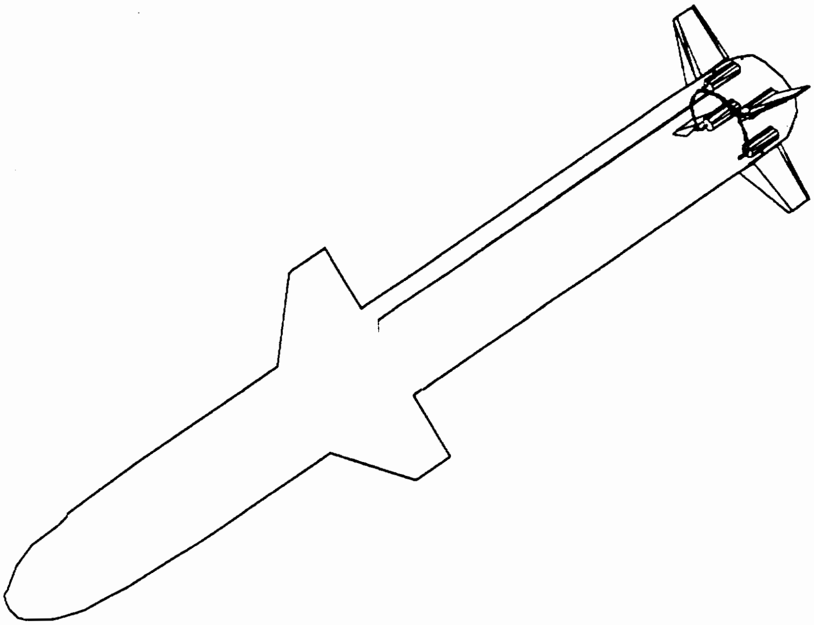


Figure 21: Viper Control System

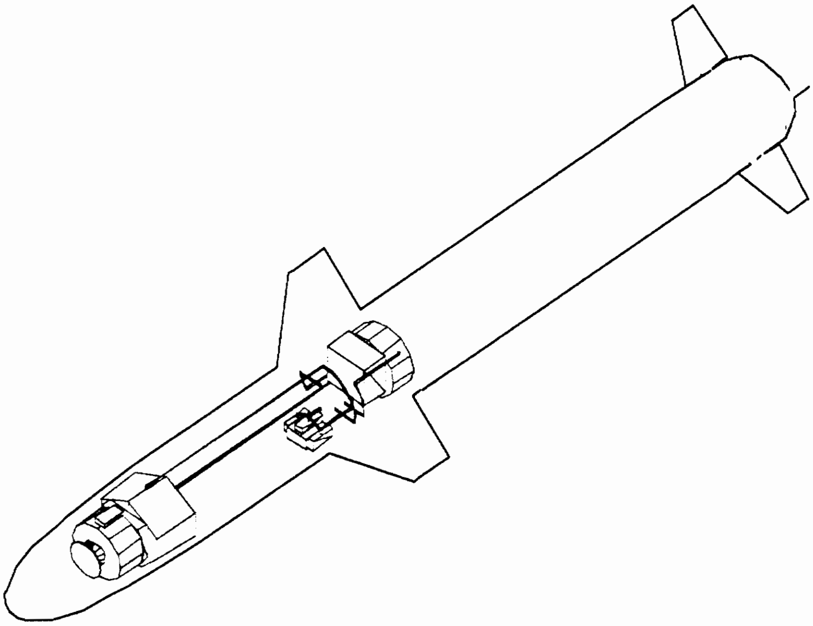


Figure 22: Viper Guidance System

Table 4. Components Included In Viper FASTGEN Model

0010	RADOME
0015	RADAR SECTION SKIN
0020	WARHEAD SECTION SKIN
0030	GUIDANCE/ELECTRONICS SKIN
0040	PROPULSION SECTION SKIN
0050	CONTROL SECTION SKIN
0110	CONDUIT
0130	AFT COVER PLATE
0410	*UPPER PORT WING*
0420	*UPPER STARBOARD WING*
0430	*LOWER PORT WING*
0440	*LOWER STARBOARD WING*
1010	NOSEPIECE
1020	NOSEPIECE MOUNTING STUD
1030	AIR INLET HOUSING
1040	*FRONT BEARING HOUSING*
1050	*FRONT BEARING AND SHAFT SUPPORT*
1060	*FRONT MOUNT*
1070	AXIAL COMPRESSOR ROTOR HOUSING
1080	AXIAL COMPRESSOR ROTOR BLADES
1090	AXIAL COMPRESSOR HUB
1100	AXIAL COMPRESSOR ROTOR DRIVE CONE
1110	AIR INLET VANES
1120	STATOR REGION
1130	COMPRESSOR HOUSING REAR SECTION
1140	FRONT SECTION OF SHAFT
1150	OIL PUMP HOUSING ASSEMBLY
1160	*FRONT BEARING ASSEMBLY*
1170	*OIL SEAL RING*
1180	RADIAL COMPRESSOR HUB
1190	*RADIAL COMPRESSOR BLADES*
1200	RADIAL DIFFUSER
1210	AXIAL DIFFUSER
1220	*COMBUSTOR HOUSING*
1230	PRIMARY AIR SWIRL VANE
1240	COMBUSTOR SHELL
1250	REAR SHAFT SECTION
1260	AIR FLOW MIXER
1270	TURBINE INLET NOZZLE
1280	TURBINE COMBUSTOR VANES
1290	TURBINE AXIAL SHAFT
1300	TURBINE AXIAL BLADES
1310	EXHAUST DUCT
1320	EXHAUST DUCT VANES
1330	EXHAUST DUCT NOZZLE
1340	*FUEL LINE*
1350	*FUEL CHAMBER*
1360	STARTER CARTRIDGE PROPELLANT
1370	STARTER CARTRIDGES (2)
1380	JUNCTION BOX
1390	*FUEL LINE, SECTION I*
1400	*FUEL LINE, SECTION II*
1410	*ELECTRONIC FUEL CONTROL*
1420	*FUEL CONTROL VALVE*
1430	BLEED AIR VALVE
1440	*FUEL LINE, START VALVE TO MAIN TANK*
1450	*FUEL LINE, MAIN TANK TO FUEL VALVE*
1460	*FUEL LINE, FUEL VALVE TO 1160 E.F.L. (SECTION I)*
1470	*REAR BEARINGS*
1550	*AIR INLET DUCT*
3010	*UPPER PORT FIN*
3020	*UPPER STARBOARD FIN*
3030	*LOWER PORT FIN*
3040	*LOWER STARBOARD FIN*
3110	*UPPER PORT SHAFT*
3120	*UPPER STARBOARD SHAFT*
3130	*LOWER PORT SHAFT*
3140	*LOWER STARBOARD SHAFT*
3210	*UPPER PORT ACTUATOR*
3220	*UPPER STARBOARD ACTUATOR*
3230	*LOWER PORT ACTUATOR*
3240	*LOWER STARBOARD ACTUATOR*
3310	*WIRE - CONTROL, TO UPPER PORT ACTUATOR*
3320	*WIRE - CONTROL,TO UPPER STARBOARD ACTUATOR*
3330	*WIRE - CONTROL,TO LOWER PORT ACTUATOR*
3340	*WIRE - CONTROL,TO LOWER STARBOARD ACTUATOR*
3530	*WIRE - FROM AUTOPILOT AFT*
4110	*FUEL SECTION 1*
4120	*FUEL SECTION 2*
4130	*FUEL SECTION 3*
4140	*FUEL SECTION 4*
4150	*FUEL SECTION 5*
4160	*FUEL SECTION 6*
4170	*FUEL SECTION 7*
4180	*FUEL SECTION 8*
4190	*FUEL SECTION 9*
4200	*FUEL SECTION 10*
4210	*FUEL SECTION 11*
4220	*FUEL SECTION 12*
4230	*FUEL SECTION 13*
4240	*FUEL SECTION 14*
4250	*FUEL SECTION 15*
5110	WARHEAD CASE
5120	*WARHEAD MAIN CHARGE*
5130	*WARHEAD BOOSTER CHARGE*
5140	*WARHEAD INITIATOR CHARGE*
5150	SAFE AND ARM DEVICE
5160	WIRE - AUTOPILOT TO S/A DEVICE
5170	WIRE - DISTRIBUTION BOX TO WARHEAD
5210	*FORWARD PORT CRUSH FUSE*
5215	WIRE - FROM FWD PORT CRUSH FUSE
5220	*FORWARD STARBOARD CRUSH FUSE*
5225	WIRE - FROM FWD STBD CRUSH FUSE
5230	*UPPER PORT CRUSH FUSE*
5235	WIRE - FROM UPPER PORT CRUSH FUSE
5240	*UPPER STARBOARD CRUSH FUSE*
5245	WIRE - FROM UPPER STBD CRUSH FUSE
6100	*GYRO BLOCK*
6110	*LONGITUDINAL ACCELEROMETER*
6120	*LATERAL ACCELEROMETER*
6130	*VERTICAL ACCELEROMETER*
6150	*WIRE - ACCELEROMETERS TO COMPUTER*
6500	*FLIGHT COMPUTER/INS*
6510	*WIRE - DIST. BLOCK TO COMPUTER*
6550	*AUTOPILOT*
6560	*WIRE - DIST. BLOCK TO AUTOPILOT*
6610	*RADAR ANTENNA/WAVEGUIDE*
6620	*RADAR ANTENNA SERVO*
6630	*RADAR TRANSMITTER*
6640	*RADAR EXCITER*
6650	*RADAR DUPLEXER*
6660	*RADAR DATA PROCESSOR*
6670	*WIRE - DISTRIBUTION BOX TO RADAR*
6680	*WIRE - RADAR TO FLIGHT COMPUTER*
7010	BULKHEAD - SENSOR /WARHEAD
7020	BULKHEAD - WARHEAD/GUIDANCE
7030	BULKHEAD - GUIDANCE /PROPULSION
7040	BULKHEAD - PROPULSION/CONTROL
7100	RADAR MOUNTING BULKHEAD
7210	FORWARD WARHEAD BRACKET
7220	AFT WARHEAD MOUNTING BRACKET
7310	FORWARD FRAME - GUIDANCE SECTION
7320	AFT FRAME - GUIDANCE SECTION
7410	FORWARD FRAME - PROPULSION
7420	FRAME II- PROPULSION SECTION
7430	FRAME III- PROPULSION SECTION
7440	FRAME IV- PROPULSION SECTION
7450	AFT FRAME - PROPULSION SECTION
7500	FRAME - CONTROL SECTION
7510	UPPER PORT ACTUATOR BRACKET
7520	UPPER STBD ACTUATOR BRACKET
7530	LOWER PORT ACTUATOR BRACKET
7540	LOWER STBD ACTUATOR BRACKET
8100	*BATTERY*
8150	*DISTRIBUTION BOX*

Vulnerable area routines, such as COVART (Computation Of Vulnerable Area and Repair Times) generate tables for single fragments or penetrators. Inputs to these routines come from shotline generators, Pdh tables, penetration data and weapon characteristic data. COVART takes into account mass and velocity decay as the fragment proceeds along the shotline and utilizes penetration equations to simulate actual conditions. The resulting product gives values for vulnerable areas for each grid cell. The total vulnerable areas for components, systems or complete targets is the sum of all the grid points that define the presented area in question.

Internal burst programs take into account burstpoints, with kill probability depending on the relation of critical components to burstpoints.

Endgame programs require a vulnerability model to account for the terminal events in an encounter between a HE warhead and the target. Evaluation usually includes warhead detonation, blast propagation, fragment flyout, impact and penetration. The numerical values for probability of kill (P_k) are determined based on encounter conditions, as well as warhead and target characteristics. Usually, numerous orientations are considered, with P_k given as a function of distance.

4.3 COVART Assessment of a Cruise Missile Target

As a final step in the analysis of the Viper cruise missile, a COVART assessment was run. The final answer in the assessment is the vulnerable area (Av) of the components, and the missile as a whole.

COVART is a FORTRAN program that determines vulnerable areas of targets that are associated with specific levels of damage caused by kinetic energy penetrators, such as warhead fragments. COVART has been used in the evaluation of manned aircraft and land-based targets, as well as missiles. Determination of repair time is useful in aircraft assessments, but is not applicable, and is usually omitted when missiles are being analyzed.

The shotlines generated from the FASTGEN model, and found in the LOS file, are essential for COVART assessments. Vulnerable areas are determined based on a preselected fragment impact speed and weight matrix. Each penetrator is evaluated along each shotline, and contributions made to target and component vulnerable areas are determined. Weight and velocity reductions are taken into account as well. Kill probabilities are determined as functions of threat impact (weight and velocity). The component probabilities are then combined, to produce defeat probabilities for a given threat against the entire target.

COVART results are useful from both lethality and survivability standpoints. From the lethality side, COVART assessments are used to determine fusing schemes and warhead designs. By evaluating a series of feasible targets, the most effective combination of fusing aimpoints and warhead case and explosive characteristics, at given standoff distances, can be determined. COVART assessments are also be used to determine the survivability of friendly systems. By estimating the threats that may be encountered, COVART analysis can be used as a tool in the design process for new aircraft and missile systems.

Information required for a COVART evaluation includes: desired attack aspects, definition of threats, kill levels and mission essential components, required outputs (vulnerable areas, repair times in the case of aircraft), and forms of output. This information is contained in a set of computer files. These include the BASIC file, THREAT file, LOS file, JTYPE file, MV file, PDH file, and HEADER file.

The BASIC file contains guidelines for running COVART, such as dimensions, program options, kill categories and aspects to be run. The BASIC file for the Viper assessment is shown in Table 5. In this case, three common aspects (0° azimuth 0° elevation, 90° azimuth 0° degree elevation, and 45° azimuth 45° elevation) were run. Usually , aspects are chosen in 30° or 45° increments in azimuth and elevation around the entire target.

The THREAT file contains input data for either fragments or projectiles, such as number of fragment weights, shapes , basic dimensions and material types. The THREAT file for the Viper assessment, entitled VIPER.FRAG, is shown in Table 6. In this case, seven fragment sizes (15, 30, 60, 120, 240, 500, 1000 grains) and ten velocities (3000, 5000, 7000, 8000, 9000, 10000, 12000, 13000, 15000 feet/sec) were considered.

The LOS file includes the shotline information, and is output from FASTGEN.

The MV file provides information on multiply vulnerable component groups. The MV file used in the Viper assessment is shown in Table 7. In this case, the control surfaces (including fins, shafts, actuators and wires) and wings are multiply vulnerable. In the case of the control surfaces, two surfaces must be disabled in order for the system to be defeated. Disabling a surface, however, requires the defeat of only one component (fin, actuator, shaft or wire).

The PDH file is a numerical representation of on the Pdh curves for the vulnerable components. The P_{dh} is expressed in terms of a function of impact weight and velocity. Data is provided for each critical component at each kill level and velocity for a given fragment weight. The P_{dh} curves represent the vulnerability of unshielded components. Shielding by other components tends to reduce the energy of incoming fragments. Typical P_{dh} curves for four component types; engine components, soft electronics, battery and autopilot, are shown in Figure 23. The PDH file, which numerically expresses the curves used in this assessment, is shown in Table 8.

The JTYPE file contains component information, such as identifying number, material type, density ratio and pointers to Pdh tables. The JTYPE file used in this assessment is shown in Table 9. Each line of this file gives information about a specific component. The first column lists the component numbers (actually, *vulnerable area names*) of the critical components, or is left blank (for non-critical components). The subsequent columns list component number, component density (0-100 percent), vulnerable area number, material type code, and applicable Pdh curve.

Information from the HEADER file is used to identify the output data specific for a given target. This information usually consists of titles and headings.

4.4 Conclusion

The overall vulnerable area for the missile, and the vulnerable areas for the components against single fragment impact are presented in Tables 10-12. Vulnerable areas for individual components are listed for fragment sizes of 30, 120, 500 and 1000 grains. Results for other sizes could be determined by interpolating these values. It should be noted that, in reality, multiple fragments are likely to be encountered. Thus, the missile is more vulnerable than these tables indicate.

The vulnerable areas for the 0° azimuth, 0° elevation aspect , which corresponds with the missile coming in head-on, are shown in Table 10. At this aspect, presented areas are small and shielding tends to protect most components. In fact, most critical components would not be considered vulnerable. The radar components, however, are located in the nose of the missile, where shielding has less of an effect. Since these components are considered "soft" electronics, they would be relatively easy to defeat. Consequently, disabling the guidance system is the only apparent means of defeating the missile from this aspect.

The vulnerable areas for the 45° azimuth, 45° elevation aspect are shown in Table 11. Compared to the results in Table 10, it can be seen that the missile and most components have larger presented and vulnerable areas. Engine and fuel components appear to be the most vulnerable at this aspect. As would be expected, larger fragments and higher velocities are likely to cause more damage. Thus, defeating the propulsion system is the most likely means of defeating the missile from this aspect.

It is apparent from this table that the multiply-vulnerable controls are not very vulnerable. This is due, in part, to the fact that the components with the largest presented areas, the control surfaces, are not considered vulnerable to single fragment impact. Smaller components are vulnerable, but their overall contributions are small, due to small presented areas and redundancy.

The vulnerable areas for the 90° azimuth, 0° elevation aspect are shown in Table 12. This aspect provides the largest presented area of the three views analyzed. Similarly, the values for vulnerable areas are slightly higher than those in Tables 10 and 11. As was the case for the 45° azimuth 45° elevation aspect, the fuel/propulsion and guidance electronics are the most vulnerable components. The electrical components are also vulnerable at this aspect. Since the electrical components are located near the autopilot and flight computer, and just forward of the fuel and propulsion sections, the aft part of the center section of the missile would be the best targeting location on this missile.

Again, the multiply-vulnerable controls are difficult to defeat. Defeating one control surface is possible, but it is unlikely that a single fragment impact will disable two surfaces.

In all views it is apparent that electronic or engine components are the most vulnerable parts of a missile. Wires and cables are crucial for proper operation of the missile, yet they are too small to be targeted. Warhead explosives are not very vulnerable, due to the fact that penetrating the hard outer casing requires a great deal of energy.

According to the COVART results, redundancy makes the control system difficult to defeat. How well a missile operates after one control surface has been defeated depends on the feedback capabilities of the system. The FMEA should give consideration to this fact. Also, location of control components would tend to make the control system seem less vulnerable than it really is. This is due to the fact that COVART only accounts for single fragment impacts and it is unlikely that components from two control surfaces will be located along one shotline.

The results presented in these tables should be viewed as a small part of a larger picture. In a real encounter, a large number of fragments, and shotlines, would be involved. As a result, the vulnerable areas of a large number of components need to be taken into account.

Generally speaking, the COVART assessment puts the results of the failure analysis in perspective. Looking at the FMEA and FTA, it seemed relatively simple to disable a missile by knocking out one component or severing one wire. While this conclusion is accurate, the results of failure analysis account for vulnerability at the system level. By taking into account component characteristics, sizes and locations, the COVART assessment provides a quantification of vulnerability at a component level.

Existing methods of vulnerability analysis have limitations. In the future, analysis methods need to take into account such real-world concerns as multiple fragment impact, degraded mode operations, and secondary effects. Many of these limitations may be overcome as computational capabilities increase.

Table 5: BASIC File For Viper Assessment

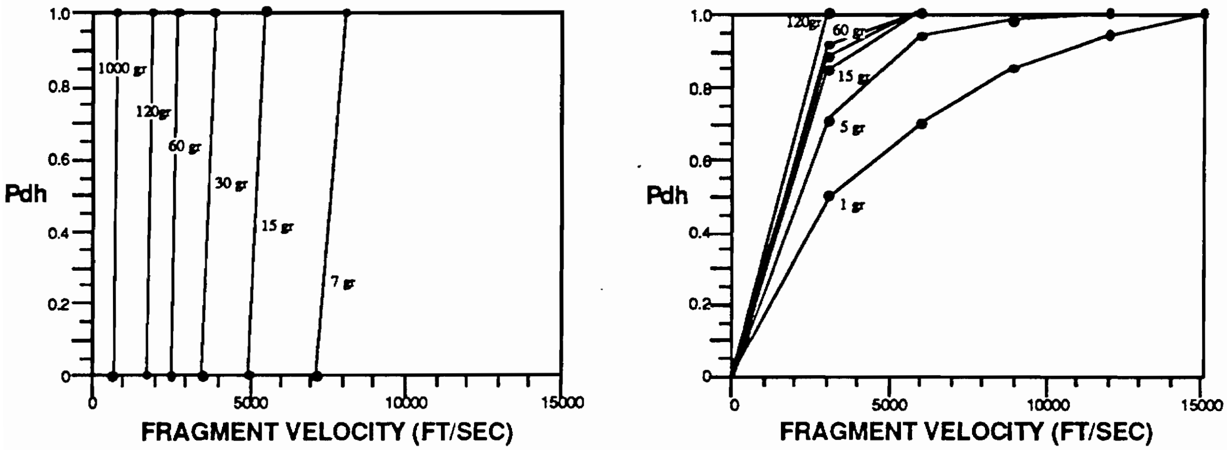
```
 5  1    6    6    7    0    9    1    8    0   50
    0    1    0    1    1    0  003
    1    0    1    0    2  -12 99999.
    1
TARGET Viper
    0    0   90    0   45   45
   20       FRAG   SYS2:[WILK.SYSENG]VIPER.FRAG
   21      JTYPE   SYS2:[WILK.SYSENG]VIPER.JTYPE
   22         MV   SYS2:[WILK.SYSENG]VIPER.MV
   23        PDH   SYS2:[WILK.SYSENG]VIPER.PDH
   24     TITLES   SYS2:[WILK.SYSENG]VIPER.HEAD
```

Table 6: THREAT File For Viper Assessment

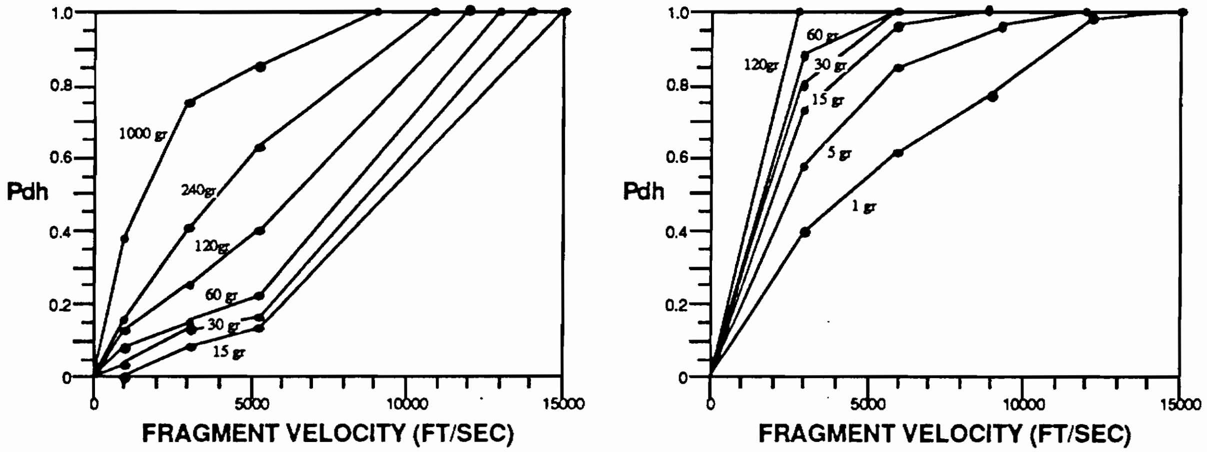
```
     FRAG
  -2   10     7      99.0     200.0
3000 5000 7000 8000 90001000011000120001300015000
  15   15 GRAIN FRAG
  30   30 GRAIN FRAG
  60   60 GRAIN FRAG
 120  120 GRAIN FRAG
 240  240 GRAIN FRAG
 500  500 GRAIN FRAG
1000 1000 GRAIN FRAG
4140341403414034140341403414034140
   1    5      .196       .196         1.
   2    5       .25        .25         1.
   3    5       .31        .31         1.
   4    5       .39        .39         1.
   5    6      .568        0.0     .66021
   6    6       .82        0.0     .45732
   7    6      1.16        0.0     .32328
```

Table 7: MV File For Viper Assessment

```
        MV
    2
KILL CATEGORY 1
*GCONTROL=UPPORT.AND.UPSTAR.AND.LOPORT.AND.LOSTAR /2/4
*SUPPORT=FIN1.OR.SHFT1.OR.ACT1.OR.WIRE1
*SUPSTAR=FIN2.OR.SHFT2.OR.ACT2.OR.WIRE2
*SLOPORT=FIN3.OR.SHFT3.OR.ACT3.OR.WIRE3
*SLOSTAR=FIN4.OR.SHFT4.OR.ACT4.OR.WIRE4
CFIN1=3010
CFIN2=3020
CFIN3=3030
CFIN4=3040
CSHFT1=3110
CSHFT2=3120
CSHFT3=3130
CSHFT4=3140
CACT1=3210
CACT2=3220
CACT3=3230
CACT4=3240
CWIRE1=3310
CWIRE2=3320
CWIRE3=3330
CWIRE4=3340
END
END OF GROUP1
*GWING=0410.AND.0420.AND.0430.AND.0440 /2/4/
END
END OF GROUP2
```



a. Engine Parts **b. Soft Electronics**



c. Battery **d. Autopilot**

Figure 23: Typical Pdh Curves

Table 8: PDH File For Viper Assessment

```
       PDH
   0.50000    2    2    0   28
  1.  6. 12. 18. 24. 60.


    1    9
    1   18ENERG
    0    0NONE
   1     5.0   6   0
   7  15  30  60 1201000   2   2   2   2   2   2
7200 0. 8100 1. 4950 0. 5525 1. 3450 0. 3900 1. 2520 0. 2780 1.   engine comps
1750 0. 1950 1.  620 0.  700 1.                                   prim frag zone
   2     5.0   1   0   0
   0   6
.900   01.500.082.500.225.000.586.500.798.00 1.0                  engine ENERG
   3     0.1   7   1
   1   2   5  15  30  601000   2   2   2   2   2   2   2
1100 0. 1225 1.  495 0.  550 1.  215 0.  245 1.  125 0.  144 1.   fuel line prim
  80 0.   90 1.   65 0.   72 1.   14 0.   17 1.                    frag zone
   4     0.1   1   0   1
   0   2
0.06   00.07 1.0                                                  fuel line NRG
   5    0.05   6   1
   1   5  15  30  60 120   5   4   2   2   2   2
 305 .51 610 .70 900 .851200 .941510 1.                           soft electron
 305 .71 610 .94 900 .981200 1.  305 .85 610 1.  305 .88 610 1.   primary frag
 305 .91 610 1.    0 0.  305 1.
   6    0.05   1   0   0
   0   6
.001   00.100.740.600.921.400.963.000.985.00 1.0                  sft elect NRG
   7    15.0   7   0
  15  30  60 120 240 5001000   3   3   3   3   3   3   3
5310   05350 .279999 .793370   03410 .786400 .70                  actuators
2375   02400 .274110 .701570   01610 .282500 .70
1125   01150 .271600 .70 800   0 835 .281010 .70
 600   0 630 .27 755 .70
   8     1.0   1   0   0
   0   6
.350   02.000.103.000.185.000.2412.00.4232.0 1.0                  actuat. Eng.
   9    0.05   5   0
  15  30  60 1201000   3   3   3   3   2
 390 0.  444 .777010 1.0 380 0.  423 .785013 1.0                  wire primary
 376 0.  419 .813015 1.0 390 0.  412 .821010 1.0 360 0.  400 1.0    frag zone
  10    0.05   1   0   1
   0   6
.001   00.020.410.040.500.080.600.160.681.66 1.0                  wire Energ
  11     3.0   6   1
   5  15  30  60 1201000   3   3   3   3   3   3
 213 0.0 242 .101510 1.0 173 0.0 193 .361210 1.0                  crush Fuzes
 111 0.0 124 .10 865 1.0  83 0.0  94 .45 616 1.0
  65 0.0  72 .55 433 1.0  37 0.0  42 .67 155 1.0
  12     3.0   1   0   1
   0   5                                                          crush Fuzes
 .06   00.070.250.150.500.600.77 5.0 1.0                            Energy
  13    0.05   6   1
   1   5  15  30  60 120   5   4   2   2   2   2
 300 .55 610 .73 915 .851220 .921525 1.                           electrical
 300 .74 610 .92 915 .981220 1.  300 .82 610 1.  300 .86 610 1.   primary frag
 300 .90 610 1.    0 0.  300 1.                                   zone
  14    0.05   1   0   0
   0   6
 001   00.100.740.600.921.400.963.000.985.00 1.0                  elect NRG
  15    0.05   6   1
   1   5  15  30  60 120   5   4   3   2   2   2
 300 .40 600 .61 900 .771212 .981515 1.                           autopilot
```

Table 8: PDH File For Viper Assessment (Continued)

```
 300 .58 600 .85 900 .961200 1.   300 .73 600 .96 890 1.           primary frag
 300 .80 600 1.   300 .88 600 1.    0 0.   290 1.                   zone
  16    0.05   1   0   0
   0   6
.002   01.000.763.000.843.000.896.000.967.00 1.0                  autoplt NRG
  17    10.0   6   1
  15  30  60 120 2401000   4   4   4   4   4   4
 100 0.   310 .08 513 .131510 1.   100 .03 310 .13 513 .161400 1.   battery
 100 .08 310 .15 513 .221300 1.   100 .13 310 .25 513 .4 1200 1.   primary frag
 100 .16 310 .41 513 .631090 1.   100 .37 310 .75 513 .85 905 1.   zone
  18    10.0   1   0   0
   0   4
0.50   01.400.108.000.6025.0 1.0                                  battery NRG
  19    1.0    4   0
  15  60 2401000   2   2   2   2
   0   09999   0   0   09999   0   0   09999   0   0   09999   0  wings/fins
  20    15.0   7   0
  15  30  60 120 240 5001000   2   2   2   2   2   2   2
3870   03955 1.02775   02850 1.01915   01984 1.01370   01450 1.0  blades
 955   01010 1.0 655   0 711 1.0 455   0 486 1.0
  21    10.0   7   0
  15  30  60 120 240 5001000   2   2   2   2   2   2   2
1965   02160 .251525   01690 .251200   01340 .25 945   01040 .25  intake
 775   0 870 .25 635   0 705 .25 545   0 600 .25
  22   300.0   2   0
 5001000   2   2
5875 0.06480 .255000 0.05513 .29                                  act. Shafts
  23    10.0   2   0
  151000   2   2
  50    0 1111.00   50    0 1111.00                               fuel
  24    10.0   7   0
  15  30  60 120 250 5001000   2   3   4   4   5   4   4
8950   09999 .057760   09100 .159999 .31                          explosive
6815   08120 .209200 .459999 .705950   07120 .209200 .809999 .89
5050   07120 .658200 .869200 .899999 .90
5025   06210 .757120 .889999 .913775   05130 .706110 .899999 .94
  25    10.0   7   0
  15  30  60 120 240 5001000   2   2   2   2   2   2   2
3888   05550 1.02800   03900 1.01965   02788 1.01390   01960 1.0  gyros
 980   01400 1.0 675   0 975 1.0 485   0 680 1.0
  26    0.0    1   0   0
   1.  4                                                          antenna
1.25 0.02.53 .555.37 .8915.8 1.0
  27    15.0   7   0
  15  30  60 120 250 5001000   2   2   2   2   2   2   2
4175   04220 1.02775   02850 1.01875   01920 1.01360   01415 1.0  servo
 955   01025 1.0 628   0 655 1.0 485   0 513 1.0
  28    15.0   7   0
  15  30  60 120 250 5001000   2   2   2   2   2   2   2
 675   0 700 .85 555   0 590 .84 455   0 495 .83 400   0 435 .83  dist.box
 350   0 388 .83 331   0 355 .83 310   0 330 .83
```

Table 9: JTYPE File For Viper Assessment

```
    JTYPE
  1      8
NON-CRIT 0010  100  227
         0015  100  2 7
         0020  100  2 7
         0030  100  2 7
         0040  100  2 7
         0050  100  2 7
         0110  100  2 7
0410     0410  100  3 7    19
0420     0420  100  4 7    19
0430     0430  100  5 7    19
0440     0440  100  6 7    19
         1010   07  2 8
         1020  100  2 1
         1030  100  2 8
1040     1040  100  712     1
1050     1050  100  812     1
1060     1060  100  912     1
         1070  100  2 1
1080     1080   32 10 1    20
         1090  100  2 1
         1100  100  2 1
         1110   20  2 8
         1120   25  2 8
         1130  100  2 8
         1140  100  2 6
1150     1150  100 11 8     1
1160     1160  100 12 6     1
1170     1170  100 1313     1
         1180  100  2 4
1190     1190   25 1416    20
         1200   25  2 8
         1210   25  2 8
1220     1220  100 15 3     3
         1230  100  2 4
         1240  100  2 1
         1250  100  2 5
         1260  100  2 1
         1270  100  2 3
         1280  100  2 3
         1290  100  2 5
         1300   25  2 5
         1310  100  2 1
         1320   04  2 1
         1330  100  2 1
1340     1340  100 16 1     3
1350     1350  100 17 3     3
         1360   79  2 7
         1370   06  2 3
         1380   60  2 1
1390     1390   28 18 8     3
1400     1400   28 19 8     3
1410     1410   30 20 8     5
1420     1420  100 21 8     3
         1430   50  2 8
1440     1440   15 22 8     3
1450     1450   15 23 8     3
1460     1460   15 24 8     3
1470     1470  100 25 6     1
1550     1550   17 26 8    21
3010     3010  100 27 7    19
3020     3020  100 28 7    19
3030     3030  100 29 7    19
3040     3040  100 30 7    19
3110     3110  100 31 6    22
3120     3120  100 32 6    22
3130     3130  100 33 6    22
3140     3140  100 34 6    22
3220     3220   40 36 8     7
3230     3230   40 37 8     7
3240     3240   40 38 8     7
3310     3310   75 3918     9
```

Table 9: JTYPE File For Viper Assessment (Continued)

3320	3320	75	4018	9
3330	3330	75	4118	9
3340	3340	75	4218	9
4100	4100	100	6954	23
4110	4110	100	7054	23
4120	4120	100	7154	23
4130	4130	100	7254	23
4140	4140	100	7354	23
4150	4150	100	7454	23
4160	4160	100	7554	23
4170	4170	10	7654	23
4180	4180	10	7754	23
4190	4190	10	7854	23
4200	4200	05	7954	23
4210	4210	05	8054	23
4220	4220	01	8154	23
4230	4230	01	8254	23
4240	4240	01	8354	23
4250	4250	01	8454	23
	5110	100	2 1	
5120	5120	100	4315	24
5130	5130	90	4415	24
5140	5140	80	4515	24
	5150	60	2 8	
	5160	75	218	
	5170	75	218	
5210	5210	25	46 1	11
	5215	75	218	
5220	5220	25	47 1	11
	5225	75	218	
5230	5230	25	48 1	11
	5235	75	218	
5240	5240	25	49 1	11
	5245	75	218	
6100	6100	45	50 8	25
6110	6110	35	51 8	13
6120	6120	35	52 8	13
6130	6130	35	53 8	13
6150	6150	75	5418	9
6500	6500	40	55 8	13
6510	6510	75	5618	9
6550	6550	30	57 8	15
6560	6560	75	5818	9
6610	6610	100	5925	26
6620	6620	40	60 8	27
6630	6630	50	61 8	13
6640	6640	50	62 8	13
6650	6650	50	63 8	13
6660	6660	50	64 8	13
6670	6670	75	6518	9
6680	6680	75	6618	9
	7010	100	2 2	
	7020	100	2 2	
	7030	100	2 2	
	7040	100	2 2	
	7100	100	2 2	
	7210	100	2 2	
	7220	100	2 2	
	7310	100	2 2	
	7320	100	2 2	
	7410	100	2 2	
	7420	100	2 2	
	7430	100	2 2	
	7440	100	2 2	
	7450	100	2 2	
	7500	100	2 2	
	7510	100	2 2	
	7520	100	2 2	
	7530	100	2 2	
	7540	100	2 2	
8100	8100	100	67 8	17
8150	8150	35	68 8	28

Table 10: Results Of COVART Assessment Of Viper : 0° Azimuth, 0° Elevation

```
ATTACK ASPECT =   0 DEGREES AZIMUTH,   0 DEGREES ELEVATION

TOTAL PRESENTED AREA =     1.29 (SQUARE FEET)

         SINGLE SHOT TOTAL VULNERABLE AREAS (SQUARE FEET)

   KILL          THREAT                           SPEED (FEET PER SECOND)
 CATEGORY                       3000   5000   7000   8000   9000  10000  11000  12000  13000  15000

 KILL 1            15 GRAIN FRAG  0.03   0.27   0.30   0.31   0.31   0.31   0.32   0.31   0.31   0.30
 MISSION           30 GRAIN FRAG  0.03   0.30   0.52   0.53   0.54   0.54   0.51   0.35   0.35   0.35
                   60 GRAIN FRAG  0.03   0.48   0.55   0.56   0.57   0.56   0.56   0.53   0.43   0.35
                  120 GRAIN FRAG  0.31   0.55   0.58   0.60   0.60   0.60   0.60   0.58   0.56   0.35
                  240 GRAIN FRAG  0.43   0.58   0.62   0.63   0.64   0.64   0.63   0.63   0.58   0.35
                  500 GRAIN FRAG  0.47   0.61   0.64   0.64   0.64   0.64   0.64   0.64   0.64   0.63
                 1000 GRAIN FRAG  0.50   0.63   0.65   0.65   0.65   0.65   0.64   0.64   0.64   0.64

ATTACK ASPECT =   0 DEGREES AZIMUTH,   0 DEGREES ELEVATION

SINGLE SHOT COMPONENT INCREMENTAL SINGLY VULNERABLE AREAS (SQUARE FEET)    FOR KILL 1     MISSION

COMPONENT     PRESENTED     THREAT                         SPEED (FEET PER SECOND)
  NAME          AREA                    3000   5000   7000   8000   9000  10000  11000  12000  13000  15000

 0410          0.03                       VULNERABLE AREA IS EQUAL TO ZERO
 0420          0.06                       VULNERABLE AREA IS EQUAL TO ZERO
 0430          0.05                       VULNERABLE AREA IS EQUAL TO ZERO
 0440          0.06                       VULNERABLE AREA IS EQUAL TO ZERO
 1040          0.00                       VULNERABLE AREA IS EQUAL TO ZERO
 1050          0.00                       VULNERABLE AREA IS EQUAL TO ZERO
 1060          0.00                       VULNERABLE AREA IS EQUAL TO ZERO
 1080          0.19                       VULNERABLE AREA IS EQUAL TO ZERO
 1150          0.00                       VULNERABLE AREA IS EQUAL TO ZERO
 1160          0.00                       VULNERABLE AREA IS EQUAL TO ZERO
 1170          0.00                       VULNERABLE AREA IS EQUAL TO ZERO
 1190          0.33                       VULNERABLE AREA IS EQUAL TO ZERO
 1220          0.47                       VULNERABLE AREA IS EQUAL TO ZERO
 1340          0.00                       VULNERABLE AREA IS EQUAL TO ZERO
 1350          0.01                       VULNERABLE AREA IS EQUAL TO ZERO
 1390          0.09                       VULNERABLE AREA IS EQUAL TO ZERO
 1400          0.03                       VULNERABLE AREA IS EQUAL TO ZERO
 1410          0.05                       VULNERABLE AREA IS EQUAL TO ZERO
 1420          0.03                       VULNERABLE AREA IS EQUAL TO ZERO
 1440          0.14                       VULNERABLE AREA IS EQUAL TO ZERO
 1450          0.05                       VULNERABLE AREA IS EQUAL TO ZERO
 1460          0.06                       VULNERABLE AREA IS EQUAL TO ZERO
 1470          0.00                       VULNERABLE AREA IS EQUAL TO ZERO
 1550          0.44                       VULNERABLE AREA IS EQUAL TO ZERO
 3010          0.03                       VULNERABLE AREA IS EQUAL TO ZERO
 3020          0.06                       VULNERABLE AREA IS EQUAL TO ZERO
 3030          0.03                       VULNERABLE AREA IS EQUAL TO ZERO
 3040          0.04                       VULNERABLE AREA IS EQUAL TO ZERO
```

Table 10: Results Of COVART Assessment Of Viper : 0°Azimuth, 0°Elevation (Continued)

```
                                                                                           COVART 3

          ATTACK ASPECT =    0 DEGREES AZIMUTH,    0 DEGREES ELEVATION

 COMPONENT     PRESENTED      THREAT                              SPEED (FEET PER SECOND)
   NAME          AREA                           3000    5000    7000    8000    9000   10000   11000   12000   13000   15000

  3110          0.03                               VULNERABLE AREA IS EQUAL TO ZERO
  3120          0.03                               VULNERABLE AREA IS EQUAL TO ZERO
  3130          0.02                               VULNERABLE AREA IS EQUAL TO ZERO
  3140          0.02                               VULNERABLE AREA IS EQUAL TO ZERO
  3210          0.03                               VULNERABLE AREA IS EQUAL TO ZERO
  3220          0.03                               VULNERABLE AREA IS EQUAL TO ZERO
  3230          0.02                               VULNERABLE AREA IS EQUAL TO ZERO
  3240          0.03                               VULNERABLE AREA IS EQUAL TO ZERO
  3310          0.03                               VULNERABLE AREA IS EQUAL TO ZERO
  3320          0.04                               VULNERABLE AREA IS EQUAL TO ZERO
  3330          0.13                               VULNERABLE AREA IS EQUAL TO ZERO
  3340          0.13                               VULNERABLE AREA IS EQUAL TO ZERO
  5120          0.49                               VULNERABLE AREA IS EQUAL TO ZERO
  5130          0.00                               VULNERABLE AREA IS EQUAL TO ZERO
  5140          0.00                               VULNERABLE AREA IS EQUAL TO ZERO
  5210          0.00                               VULNERABLE AREA IS EQUAL TO ZERO
  5220          0.00                               VULNERABLE AREA IS EQUAL TO ZERO
  5230          0.00                               VULNERABLE AREA IS EQUAL TO ZERO
  5240          0.01                               VULNERABLE AREA IS EQUAL TO ZERO
  6100          0.06                               VULNERABLE AREA IS EQUAL TO ZERO
  6110          0.01                               VULNERABLE AREA IS EQUAL TO ZERO
  6120          0.01                               VULNERABLE AREA IS EQUAL TO ZERO
  6130          0.02                               VULNERABLE AREA IS EQUAL TO ZERO
  6150          0.08                               VULNERABLE AREA IS EQUAL TO ZERO
  6500          0.20                               VULNERABLE AREA IS EQUAL TO ZERO
  6510          0.09                               VULNERABLE AREA IS EQUAL TO ZERO
  6550          0.48                               VULNERABLE AREA IS EQUAL TO ZERO
  6560          0.09                               VULNERABLE AREA IS EQUAL TO ZERO
  6610          0.04        30 GRAIN FRAG      0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                           120 GRAIN FRAG      0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                           500 GRAIN FRAG      0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                          1000 GRAIN FRAG      0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
  6620          0.02                               VULNERABLE AREA IS EQUAL TO ZERO
  6630          0.33        30 GRAIN FRAG      0.00    0.26    0.28    0.29    0.30    0.30    0.30    0.30    0.30    0.30
                           120 GRAIN FRAG      0.19    0.29    0.30    0.30    0.30    0.30    0.30    0.30    0.30    0.30
                           500 GRAIN FRAG      0.26    0.30    0.30    0.30    0.30    0.30    0.30    0.30    0.30    0.30
                          1000 GRAIN FRAG      0.27    0.30    0.30    0.30    0.30    0.30    0.30    0.30    0.30    0.30
  6640          0.16                               VULNERABLE AREA IS EQUAL TO ZERO
  6650          0.02        30 GRAIN FRAG      0.00    0.00    0.02    0.02    0.02    0.02    0.01    0.00    0.00    0.00
                           120 GRAIN FRAG      0.01    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.00
                           500 GRAIN FRAG      0.01    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02
                          1000 GRAIN FRAG      0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02
  6660          0.57        30 GRAIN FRAG      0.00    0.00    0.17    0.17    0.17    0.17    0.15    0.01    0.00    0.00
                           120 GRAIN FRAG      0.06    0.19    0.19    0.20    0.21    0.20    0.20    0.20    0.18    0.00
                           500 GRAIN FRAG      0.15    0.22    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24
                          1000 GRAIN FRAG      0.16    0.22    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24
  6670          0.15                               VULNERABLE AREA IS EQUAL TO ZERO
  6680          0.08        30 GRAIN FRAG      0.00    0.01    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02
                           120 GRAIN FRAG      0.02    0.02    0.03    0.03    0.03    0.03    0.03    0.02    0.02    0.02
                           500 GRAIN FRAG      0.02    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04
                          1000 GRAIN FRAG      0.02    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04
```

Table 10: Results Of COVART Assessment Of Viper : 0° Azimuth, 0° Elevation (Continued)

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                                                                                                          COVART 3

      ATTACK ASPECT =    0 DEGREES AZIMUTH,    0 DEGREES ELEVATION

COMPONENT       PRESENTED      THREAT                                SPEED (FEET PER SECOND)
  NAME            AREA                          3000    5000    7000    8000    9000  10000   11000   12000   13000   15000

 8100             0.17                             VULNERABLE AREA IS EQUAL TO ZERO
 8150             0.01                             VULNERABLE AREA IS EQUAL TO ZERO
 4100             0.01                             VULNERABLE AREA IS EQUAL TO ZERO
 4110             0.06                             VULNERABLE AREA IS EQUAL TO ZERO
 4120             0.03                             VULNERABLE AREA IS EQUAL TO ZERO
 4130             0.08                             VULNERABLE AREA IS EQUAL TO ZERO
 4140             0.08                             VULNERABLE AREA IS EQUAL TO ZERO
 4150             0.05                             VULNERABLE AREA IS EQUAL TO ZERO
 4160             0.06                             VULNERABLE AREA IS EQUAL TO ZERO
 4170             0.05                             VULNERABLE AREA IS EQUAL TO ZERO
 4180             0.03                             VULNERABLE AREA IS EQUAL TO ZERO
 4190             0.06                             VULNERABLE AREA IS EQUAL TO ZERO
 4200             0.04                             VULNERABLE AREA IS EQUAL TO ZERO
 4210             0.09                             VULNERABLE AREA IS EQUAL TO ZERO
 4220             0.03                             VULNERABLE AREA IS EQUAL TO ZERO
 4230             0.08                             VULNERABLE AREA IS EQUAL TO ZERO
 4240             0.08                             VULNERABLE AREA IS EQUAL TO ZERO
 4250             0.01                             VULNERABLE AREA IS EQUAL TO ZERO

      SINGLE SHOT VULNERABLE AREAS OF MULTIPLY-VULNERABLE GROUPS (SQUARE FEET)
          (THESE RESULTS ARE INCLUDED IN THE TOTAL TARGET VULNERABLE AREAS)


       KILL       GROUP   PRESENTED    THREAT                            SPEED (FEET PER SECOND)
     CATEGORY     NAME       AREA                    3000    5000    7000    8000    9000  10000   11000   12000   13000   15000

    KILL 1       CONTROL     0.06                    VULNERABLE AREA IS EQUAL TO ZERO
    MISSION

      SYSTEM MULTIPLY VULNERABLE AREAS (SQUARE FEET)   FOR  KILL 1      MISSION

      COMPONENT   PRESENTED    THREAT                            SPEED (FEET PER SECOND)
        NAME         AREA                  3000    5000    7000    8000    9000  10000   11000   12000   13000   15000

       UPPORT       0.10                     VULNERABLE AREA IS EQUAL TO ZERO
       UPSTAR       0.12                     VULNERABLE AREA IS EQUAL TO ZERO
       LOPORT       0.17                     VULNERABLE AREA IS EQUAL TO ZERO
       LOSTAR       0.18                     VULNERABLE AREA IS EQUAL TO ZERO
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Table 11: Results Of COVART Assessment Of Viper : 45° Azimuth, 45° Elevation

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ATTACK ASPECT =  45 DEGREES AZIMUTH,  45 DEGREES ELEVATION

TOTAL PRESENTED AREA =     16.71 (SQUARE FEET)


VULNERABLE COMPONENT PRESENTED AREAS IN (SQUARE FEET)


         SINGLE SHOT TOTAL VULNERABLE AREAS (SQUARE FEET)


   KILL              THREAT                                SPEED (FEET PER SECOND)
 CATEGORY                           3000    5000    7000    8000    9000   10000   11000   12000   13000   15000


  KILL 1             15 GRAIN FRAG  3.19    5.34    4.80    4.53    4.15    3.84    3.58    3.29    3.24    3.20
  MISSION            30 GRAIN FRAG  3.89    6.17    5.81    5.53    5.41    5.14    4.91    4.65    4.38    3.97
                     60 GRAIN FRAG  4.29    6.76    7.23    7.17    7.12    7.08    6.97    6.91    6.85    5.85
                    120 GRAIN FRAG  6.37    7.48    7.61    7.53    7.52    7.50    7.47    7.42    7.31    7.16
                    240 GRAIN FRAG  6.96    7.76    7.97    7.85    7.73    7.66    7.60    7.56    7.46    7.31
                    500 GRAIN FRAG  7.25    7.98    8.15    8.04    7.98    7.92    7.82    7.78    7.71    7.52
                   1000 GRAIN FRAG  7.53    8.21    8.31    8.31    8.15    8.06    8.01    7.99    7.91    7.65


ATTACK ASPECT =  45 DEGREES AZIMUTH,  45 DEGREES ELEVATION


SINGLE SHOT COMPONENT INCREMENTAL SINGLY VULNERABLE AREAS (SQUARE FEET)    FOR KILL 1      MISSION

COMPONENT      PRESENTED      THREAT                                SPEED (FEET PER SECOND)
  NAME           AREA                     3000    5000    7000    8000    9000   10000   11000   12000   13000   15000


0410            0.19                          VULNERABLE AREA IS EQUAL TO ZERO
0420            0.82                          VULNERABLE AREA IS EQUAL TO ZERO
0430            0.81                          VULNERABLE AREA IS EQUAL TO ZERO
0440            0.22                          VULNERABLE AREA IS EQUAL TO ZERO
1040            0.04       30 GRAIN FRAG  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                          120 GRAIN FRAG  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                          500 GRAIN FRAG  0.01    0.02    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
                         1000 GRAIN FRAG  0.02    0.02    0.02    0.02    0.02    0.02    0.01    0.01    0.01    0.01
1050            0.16       30 GRAIN FRAG  0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                          120 GRAIN FRAG  0.00    0.01    0.01    0.01    0.01    0.00    0.00    0.00    0.00    0.00
                          500 GRAIN FRAG  0.00    0.02    0.02    0.02    0.02    0.01    0.01    0.01    0.01    0.01
                         1000 GRAIN FRAG  0.01    0.04    0.04    0.03    0.03    0.02    0.02    0.02    0.01    0.01
1060            0.01                          VULNERABLE AREA IS EQUAL TO ZERO
1080            0.23       30 GRAIN FRAG  0.00    0.00    0.01    0.01    0.01    0.01    0.01    0.01    0.00    0.00
                          120 GRAIN FRAG  0.03    0.08    0.07    0.07    0.07    0.06    0.05    0.04    0.03    0.03
                          500 GRAIN FRAG  0.08    0.09    0.09    0.09    0.09    0.08    0.08    0.08    0.06    0.05
                         1000 GRAIN FRAG  0.08    0.09    0.10    0.10    0.09    0.09    0.08    0.08    0.08    0.04
1150            0.05                          VULNERABLE AREA IS EQUAL TO ZERO
1160            0.03                          VULNERABLE AREA IS EQUAL TO ZERO
1170            0.04                          VULNERABLE AREA IS EQUAL TO ZERO
1190            0.39       30 GRAIN FRAG  0.00    0.01    0.05    0.06    0.06    0.05    0.04    0.01    0.01    0.00
                          120 GRAIN FRAG  0.13    0.19    0.18    0.18    0.18    0.18    0.19    0.19    0.14    0.08
                          500 GRAIN FRAG  0.18    0.21    0.21    0.21    0.21    0.21    0.21    0.21    0.21    0.10
                         1000 GRAIN FRAG  0.19    0.22    0.22    0.22    0.21    0.21    0.21    0.21    0.21    0.12
```

Table 11: Results Of COVART Assessment Of Viper : 45°Azimuth, 45°Elevation (Continued)

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                                                                                                   COVART 3
      ATTACK ASPECT =  45 DEGREES AZIMUTH,  45 DEGREES ELEVATION

COMPONENT     PRESENTED     THREAT                                 SPEED (FEET PER SECOND)
  NAME          AREA                      3000    5000    7000    8000    9000   10000   11000   12000   13000   15000

 1220           1.38      30 GRAIN FRAG   0.62    0.78    0.78    0.79    0.79    0.80    0.81    0.81    0.81    0.82
                         120 GRAIN FRAG   0.76    0.81    0.84    0.86    0.86    0.85    0.85    0.86    0.85    0.85
                         500 GRAIN FRAG   0.78    0.84    0.85    0.85    0.85    0.86    0.86    0.86    0.86    0.85
                        1000 GRAIN FRAG   0.81    0.85    0.86    0.87    0.87    0.87    0.87    0.87    0.86    0.86
 1340           0.03                          VULNERABLE AREA IS EQUAL TO ZERO
 1350           0.14      30 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         120 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         500 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                        1000 GRAIN FRAG   0.00    0.01    0.02    0.01    0.00    0.00    0.00    0.00    0.00    0.00
 1390           0.13      30 GRAIN FRAG   0.10    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13
                         120 GRAIN FRAG   0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13
                         500 GRAIN FRAG   0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13
                        1000 GRAIN FRAG   0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.13
 1400           0.13      30 GRAIN FRAG   0.09    0.10    0.10    0.10    0.10    0.10    0.10    0.10    0.10    0.10
                         120 GRAIN FRAG   0.10    0.10    0.10    0.10    0.11    0.11    0.11    0.11    0.11    0.11
                         500 GRAIN FRAG   0.10    0.10    0.11    0.11    0.11    0.11    0.11    0.11    0.11    0.11
                        1000 GRAIN FRAG   0.10    0.11    0.11    0.11    0.11    0.11    0.11    0.11    0.11    0.11
 1410           0.29      30 GRAIN FRAG   0.00    0.00    0.01    0.02    0.03    0.04    0.05    0.05    0.05    0.05
                         120 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         500 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                        1000 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
 1420           0.05      30 GRAIN FRAG   0.00    0.00    0.01    0.01    0.01    0.01    0.01    0.01    0.02    0.02
                         120 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         500 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                        1000 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
 1440           0.10      30 GRAIN FRAG   0.05    0.06    0.06    0.06    0.07    0.07    0.07    0.07    0.08    0.08
                         120 GRAIN FRAG   0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
                         500 GRAIN FRAG   0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
                        1000 GRAIN FRAG   0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
 1450           0.07      30 GRAIN FRAG   0.00    0.00    0.01    0.02    0.02    0.03    0.03    0.04    0.04    0.04
                         120 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         500 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                        1000 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
 1460           0.09      30 GRAIN FRAG   0.00    0.06    0.06    0.06    0.06    0.06    0.07    0.07    0.07    0.07
                         120 GRAIN FRAG   0.06    0.06    0.07    0.07    0.07    0.07    0.07    0.07    0.07    0.07
                         500 GRAIN FRAG   0.06    0.07    0.07    0.07    0.07    0.07    0.07    0.07    0.07    0.07
                        1000 GRAIN FRAG   0.06    0.07    0.07    0.07    0.07    0.07    0.07    0.07    0.07    0.07
 1470           0.02                          VULNERABLE AREA IS EQUAL TO ZERO
 1550           2.16                          VULNERABLE AREA IS EQUAL TO ZERO
 3010           0.04                          VULNERABLE AREA IS EQUAL TO ZERO
 3020           0.38                          VULNERABLE AREA IS EQUAL TO ZERO
 3030           0.37                          VULNERABLE AREA IS EQUAL TO ZERO
 3040           0.08                          VULNERABLE AREA IS EQUAL TO ZERO
 3110           0.01                          VULNERABLE AREA IS EQUAL TO ZERO
 3120           0.03                          VULNERABLE AREA IS EQUAL TO ZERO
 3130           0.03                          VULNERABLE AREA IS EQUAL TO ZERO
 3140           0.01                          VULNERABLE AREA IS EQUAL TO ZERO
 3210           0.06                          VULNERABLE AREA IS EQUAL TO ZERO
 3220           0.10                          VULNERABLE AREA IS EQUAL TO ZERO
 3230           0.08                          VULNERABLE AREA IS EQUAL TO ZERO
```

Table 11: Results Of COVART Assessment Of Viper : 45°Azimuth, 45°Elevation (Continued)

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                                                                                COVART 3


       ATTACK ASPECT =  45 DEGREES AZIMUTH,  45 DEGREES ELEVATION

  COMPONENT     PRESENTED     THREAT                              SPEED (FEET PER SECOND)
    NAME          AREA                    3000   5000   7000   8000   9000  10000  11000  12000  13000  15000


   3240           0.08                       VULNERABLE AREA IS EQUAL TO ZERO
   3310           0.03                       VULNERABLE AREA IS EQUAL TO ZERO
   3320           0.02                       VULNERABLE AREA IS EQUAL TO ZERO
   3330           0.10                       VULNERABLE AREA IS EQUAL TO ZERO
   3340           0.09                       VULNERABLE AREA IS EQUAL TO ZERO
   5120           1.40      30 GRAIN FRAG  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
                           120 GRAIN FRAG  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
                           500 GRAIN FRAG  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
                          1000 GRAIN FRAG  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.01   0.01   0.01
   5130           0.06                       VULNERABLE AREA IS EQUAL TO ZERO
   5140           0.21                       VULNERABLE AREA IS EQUAL TO ZERO
   5210           0.01                       VULNERABLE AREA IS EQUAL TO ZERO
   5220           0.00                       VULNERABLE AREA IS EQUAL TO ZERO
   5230           0.01                       VULNERABLE AREA IS EQUAL TO ZERO
   5240           0.01                       VULNERABLE AREA IS EQUAL TO ZERO
   6100           0.15      30 GRAIN FRAG  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
                           120 GRAIN FRAG  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
                           500 GRAIN FRAG  0.00   0.01   0.01   0.01   0.01   0.00   0.00   0.00   0.00   0.00
                          1000 GRAIN FRAG  0.01   0.01   0.01   0.01   0.01   0.01   0.01   0.01   0.01   0.00
   6110           0.06                       VULNERABLE AREA IS EQUAL TO ZERO
   6120           0.06      30 GRAIN FRAG  0.00   0.01   0.01   0.02   0.02   0.02   0.02   0.02   0.02   0.02
                           120 GRAIN FRAG  0.01   0.02   0.03   0.03   0.03   0.03   0.02   0.02   0.02   0.02
                           500 GRAIN FRAG  0.02   0.03   0.03   0.04   0.03   0.03   0.03   0.02   0.02   0.02
                          1000 GRAIN FRAG  0.02   0.03   0.04   0.04   0.04   0.03   0.03   0.03   0.02   0.02
   6130           0.07                       VULNERABLE AREA IS EQUAL TO ZERO
   6150           0.15      30 GRAIN FRAG  0.01   0.01   0.02   0.01   0.01   0.01   0.01   0.01   0.01   0.01
                           120 GRAIN FRAG  0.01   0.03   0.03   0.02   0.01   0.01   0.01   0.01   0.01   0.01
                           500 GRAIN FRAG  0.04   0.04   0.04   0.04   0.03   0.02   0.02   0.02   0.02   0.02
                          1000 GRAIN FRAG  0.04   0.04   0.04   0.04   0.04   0.03   0.02   0.02   0.02   0.02
   6500           0.53      30 GRAIN FRAG  0.00   0.27   0.31   0.31   0.32   0.32   0.32   0.32   0.32   0.32
                           120 GRAIN FRAG  0.23   0.32   0.32   0.33   0.33   0.33   0.33   0.33   0.33   0.33
                           500 GRAIN FRAG  0.27   0.33   0.33   0.33   0.32   0.32   0.32   0.33   0.33   0.33
                          1000 GRAIN FRAG  0.28   0.33   0.32   0.32   0.33   0.33   0.33   0.33   0.33   0.33
   6510           0.11                       VULNERABLE AREA IS EQUAL TO ZERO
   6550           0.65      30 GRAIN FRAG  0.00   0.18   0.22   0.23   0.25   0.25   0.25   0.26   0.26   0.26
                           120 GRAIN FRAG  0.19   0.26   0.27   0.27   0.27   0.28   0.28   0.28   0.28   0.28
                           500 GRAIN FRAG  0.23   0.27   0.28   0.28   0.28   0.28   0.28   0.29   0.29   0.30
                          1000 GRAIN FRAG  0.24   0.28   0.28   0.28   0.29   0.29   0.30   0.32   0.32   0.32
   6560           0.13      30 GRAIN FRAG  0.05   0.05   0.06   0.06   0.06   0.06   0.07   0.07   0.07   0.06
                           120 GRAIN FRAG  0.06   0.06   0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09
                           500 GRAIN FRAG  0.07   0.07   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10
                          1000 GRAIN FRAG  0.07   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10
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Table 11: Results Of COVART Assessment Of Viper : 45°Azimuth, 45°Elevation (Continued)

ATTACK ASPECT = 45 DEGREES AZIMUTH, 45 DEGREES ELEVATION

COMPONENT NAME	PRESENTED AREA	THREAT	SPEED (FEET PER SECOND)									
			3000	5000	7000	8000	9000	10000	11000	12000	13000	15000
6610	0.14	30 GRAIN FRAG	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
		120 GRAIN FRAG	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
		500 GRAIN FRAG	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
		1000 GRAIN FRAG	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
6620	0.08	30 GRAIN FRAG	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
		120 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
		500 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		1000 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
6630	0.59	30 GRAIN FRAG	0.00	0.16	0.21	0.19	0.20	0.20	0.20	0.20	0.20	0.20
		120 GRAIN FRAG	0.23	0.40	0.33	0.20	0.20	0.20	0.20	0.20	0.20	0.20
		500 GRAIN FRAG	0.30	0.41	0.41	0.31	0.29	0.27	0.20	0.20	0.20	0.20
		1000 GRAIN FRAG	0.31	0.41	0.41	0.41	0.29	0.27	0.26	0.24	0.20	0.20
6640	0.32	30 GRAIN FRAG	0.00	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
		120 GRAIN FRAG	0.06	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
		500 GRAIN FRAG	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
		1000 GRAIN FRAG	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
6650	0.06	30 GRAIN FRAG	0.00	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
		120 GRAIN FRAG	0.04	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
		500 GRAIN FRAG	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
		1000 GRAIN FRAG	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
6660	0.99	30 GRAIN FRAG	0.00	0.47	0.58	0.60	0.65	0.65	0.65	0.64	0.64	0.64
		120 GRAIN FRAG	0.46	0.63	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
		500 GRAIN FRAG	0.55	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
		1000 GRAIN FRAG	0.56	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
6670	0.38	30 GRAIN FRAG	0.23	0.28	0.29	0.30	0.30	0.30	0.31	0.31	0.32	0.32
		120 GRAIN FRAG	0.31	0.32	0.35	0.35	0.36	0.37	0.37	0.37	0.37	0.37
		500 GRAIN FRAG	0.35	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
		1000 GRAIN FRAG	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
6680	0.41		VULNERABLE AREA IS EQUAL TO ZERO									
8100	0.63	30 GRAIN FRAG	0.02	0.04	0.04	0.05	0.06	0.06	0.06	0.06	0.05	0.04
		120 GRAIN FRAG	0.07	0.12	0.16	0.18	0.20	0.22	0.23	0.24	0.25	0.27
		500 GRAIN FRAG	0.17	0.27	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
		1000 GRAIN FRAG	0.27	0.36	0.39	0.40	0.40	0.39	0.38	0.37	0.36	0.36
8150	0.35	30 GRAIN FRAG	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
		120 GRAIN FRAG	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00
		500 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
		1000 GRAIN FRAG	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01
4100	0.04		VULNERABLE AREA IS EQUAL TO ZERO									
4110	1.19		VULNERABLE AREA IS EQUAL TO ZERO									
4120	1.15	30 GRAIN FRAG	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
		120 GRAIN FRAG	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
		500 GRAIN FRAG	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
		1000 GRAIN FRAG	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
4130	1.26	30 GRAIN FRAG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		120 GRAIN FRAG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		500 GRAIN FRAG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1000 GRAIN FRAG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4140	1.44	30 GRAIN FRAG	0.00	0.04	0.05	0.05	0.05	0.05	0.04	0.04	0.03	0.01
		120 GRAIN FRAG	0.03	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
		500 GRAIN FRAG	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04
		1000 GRAIN FRAG	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04

Table 11: Results Of COVART Assessment Of Viper : 45°Azimuth, 45°Elevation (Continued)

ATTACK ASPECT = 45 DEGREES AZIMUTH, 45 DEGREES ELEVATION

COMPONENT NAME	PRESENTED AREA	THREAT	SPEED (FEET PER SECOND)									
			3000	5000	7000	8000	9000	10000	11000	12000	13000	15000
4150	1.59	30 GRAIN FRAG	0.00	0.06	0.08	0.08	0.08	0.07	0.07	0.05	0.03	0.02
		120 GRAIN FRAG	0.06	0.08	0.08	0.08	0.08	0.06	0.06	0.06	0.06	0.06
		500 GRAIN FRAG	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.06	0.06
		1000 GRAIN FRAG	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.06
4160	1.83	30 GRAIN FRAG	0.08	0.08	0.11	0.10	0.09	0.08	0.05	0.05	0.04	0.03
		120 GRAIN FRAG	0.08	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.08
		500 GRAIN FRAG	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.08	0.08	0.08
		1000 GRAIN FRAG	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.08
4170	2.14	30 GRAIN FRAG	0.07	0.07	0.09	0.08	0.06	0.04	0.04	0.04	0.03	0.03
		120 GRAIN FRAG	0.07	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		500 GRAIN FRAG	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07
		1000 GRAIN FRAG	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07
4180	2.20	30 GRAIN FRAG	0.18	0.18	0.21	0.16	0.11	0.10	0.09	0.08	0.07	0.05
		120 GRAIN FRAG	0.19	0.19	0.20	0.19	0.19	0.18	0.18	0.18	0.18	0.18
		500 GRAIN FRAG	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.18
		1000 GRAIN FRAG	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.18
4190	2.31	30 GRAIN FRAG	0.14	0.14	0.15	0.08	0.08	0.07	0.06	0.05	0.05	0.03
		120 GRAIN FRAG	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14
		500 GRAIN FRAG	0.15	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.14
		1000 GRAIN FRAG	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.14	0.14
4200	2.29	30 GRAIN FRAG	0.15	0.15	0.12	0.10	0.09	0.08	0.07	0.06	0.05	0.03
		120 GRAIN FRAG	0.15	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17
		500 GRAIN FRAG	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17
		1000 GRAIN FRAG	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17
4210	2.38	30 GRAIN FRAG	0.19	0.19	0.12	0.10	0.09	0.08	0.06	0.06	0.04	0.02
		120 GRAIN FRAG	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
		500 GRAIN FRAG	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20
		1000 GRAIN FRAG	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
4220	2.24	30 GRAIN FRAG	0.19	0.20	0.12	0.10	0.09	0.08	0.07	0.06	0.04	0.03
		120 GRAIN FRAG	0.20	0.22	0.22	0.22	0.22	0.22	0.22	0.21	0.20	0.21
		500 GRAIN FRAG	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
		1000 GRAIN FRAG	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.23
4230	2.26	30 GRAIN FRAG	0.22	0.24	0.15	0.13	0.12	0.10	0.08	0.07	0.05	0.05
		120 GRAIN FRAG	0.22	0.27	0.27	0.26	0.25	0.25	0.25	0.26	0.25	0.25
		500 GRAIN FRAG	0.27	0.27	0.28	0.27	0.27	0.27	0.26	0.26	0.26	0.26
		1000 GRAIN FRAG	0.27	0.27	0.28	0.28	0.27	0.27	0.27	0.27	0.28	0.27
4240	2.02	30 GRAIN FRAG	0.44	0.58	0.41	0.37	0.35	0.30	0.26	0.20	0.15	0.08
		120 GRAIN FRAG	0.57	0.61	0.61	0.61	0.60	0.60	0.60	0.58	0.58	0.60
		500 GRAIN FRAG	0.61	0.61	0.62	0.61	0.61	0.61	0.61	0.61	0.60	0.60
		1000 GRAIN FRAG	0.61	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.60	0.60
4250	1.46	30 GRAIN FRAG	0.87	1.30	0.90	0.83	0.72	0.59	0.49	0.38	0.25	0.08
		120 GRAIN FRAG	1.30	1.39	1.42	1.43	1.43	1.42	1.41	1.40	1.36	1.26
		500 GRAIN FRAG	1.37	1.44	1.45	1.45	1.45	1.44	1.43	1.42	1.40	1.38
		1000 GRAIN FRAG	1.40	1.45	1.46	1.46	1.46	1.45	1.44	1.42	1.42	1.39

Table 11: Results Of COVART Assessment Of Viper : 45°Azimuth, 45°Elevation (Continued)

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                                                                                          COVART 3


 SINGLE SHOT VULNERABLE AREAS OF MULTIPLY-VULNERABLE GROUPS (SQUARE FEET)
     (THESE RESULTS ARE INCLUDED IN THE TOTAL TARGET VULNERABLE AREAS)

    KILL        GROUP   PRESENTED    THREAT                                   SPEED (FEET PER SECOND)
  CATEGORY      NAME      AREA                          3000    5000    7000    8000    9000   10000   11000   12000   13000 . 15000


KILL 1         CONTROL    0.06        30 GRAIN FRAG     0.01    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02
                                     120 GRAIN FRAG     0.02    0.04    0.04    0.04    0.04    0.03    0.03    0.03    0.03    0.03
                                     500 GRAIN FRAG     0.04    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.04    0.04
                                    1000 GRAIN FRAG     0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.04

 ATTACK ASPECT =  45 DEGREES AZIMUTH,  45 DEGREES ELEVATION


 SYSTEM MULTIPLY VULNERABLE AREAS (SQUARE FEET)   FOR  KILL 1      MISSION


 COMPONENT   PRESENTED     THREAT                                 SPEED (FEET PER SECOND)
   NAME        AREA                      3000    5000    7000    8000    9000   10000   11000   12000   13000   15000


  UPPORT       0.11       30 GRAIN FRAG  0.01    0.02    0.02    0.02    0.02    0.02    0.02    0.01    0.01    0.01
                         120 GRAIN FRAG  0.02    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                         500 GRAIN FRAG  0.03    0.03    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.03
                        1000 GRAIN FRAG  0.03    0.03    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04
  UPSTAR       0.50       30 GRAIN FRAG  0.00    0.01    0.03    0.03    0.02    0.02    0.02    0.02    0.02    0.01
                         120 GRAIN FRAG  0.02    0.05    0.06    0.06    0.07    0.06    0.06    0.06    0.06    0.06
                         500 GRAIN FRAG  0.06    0.06    0.07    0.06    0.06    0.07    0.07    0.07    0.07    0.07
                        1000 GRAIN FRAG  0.06    0.07    0.07    0.07    0.07    0.07    0.07    0.07    0.07    0.07
  LOPORT       0.56       30 GRAIN FRAG  0.06    0.07    0.10    0.10    0.09    0.09    0.10    0.09    0.09    0.08
                         120 GRAIN FRAG  0.09    0.12    0.13    0.13    0.13    0.13    0.13    0.13    0.13    0.14
                         500 GRAIN FRAG  0.12    0.12    0.12    0.12    0.12    0.13    0.13    0.13    0.13    0.14
                        1000 GRAIN FRAG  0.12    0.12    0.12    0.12    0.12    0.12    0.13    0.13    0.13    0.14
  LOSTAR       0.19       30 GRAIN FRAG  0.00    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
                         120 GRAIN FRAG  0.01    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.01
                         500 GRAIN FRAG  0.01    0.04    0.03    0.03    0.03    0.02    0.02    0.02    0.02    0.02
                        1000 GRAIN FRAG  0.02    0.03    0.04    0.03    0.03    0.03    0.02    0.02    0.03    0.02
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Table 12: Results Of COVART Assessment Of Viper : 90°Azimuth, 0°Elevation

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      ATTACK ASPECT =  90 DEGREES AZIMUTH,   0 DEGREES ELEVATION

      TOTAL PRESENTED AREA =    18.35 (SQUARE FEET)


      VULNERABLE COMPONENT PRESENTED AREAS IN (SQUARE FEET)


             SINGLE SHOT TOTAL VULNERABLE AREAS (SQUARE FEET)


          KILL          THREAT                                   SPEED (FEET PER SECOND)
        CATEGORY                       3000    5000    7000    8000    9000   10000   11000   12000   13000   15000


       KILL 1            15 GRAIN FRAG   4.22    4.94    4.49    4.21    3.96    3.76    3.61    3.56    3.52    3.37
       MISSION           30 GRAIN FRAG   5.16    6.57    5.80    5.57    5.27    4.96    4.66    4.44    4.37    4.17
                         60 GRAIN FRAG   5.40    7.39    7.74    7.74    7.58    7.38    7.31    7.24    6.31    5.70
                        120 GRAIN FRAG   6.95    7.95    8.09    8.15    8.15    8.06    8.00    7.88    7.88    6.71
                        240 GRAIN FRAG   7.49    8.25    8.35    8.35    8.33    8.25    8.19    8.13    8.06    7.83
                        500 GRAIN FRAG   7.78    8.45    8.61    8.63    8.62    8.59    8.52    8.50    8.49    8.34
                       1000 GRAIN FRAG   8.09    8.60    8.71    8.75    8.78    8.74    8.72    8.64    8.58    8.58


      ATTACK ASPECT =  90 DEGREES AZIMUTH,   0 DEGREES ELEVATION


  SINGLE SHOT COMPONENT INCREMENTAL SINGLY VULNERABLE AREAS (SQUARE FEET)    FOR KILL 1      MISSION

  COMPONENT    PRESENTED     THREAT                                  SPEED (FEET PER SECOND)
    NAME         AREA                  3000    5000    7000    8000    9000   10000   11000   12000   13000   15000


   0410         0.74                      VULNERABLE AREA IS EQUAL TO ZERO
   0420         0.74                      VULNERABLE AREA IS EQUAL TO ZERO
   0430         0.73                      VULNERABLE AREA IS EQUAL TO ZERO
   0440         0.73                      VULNERABLE AREA IS EQUAL TO ZERO
   1040         0.02      30 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         120 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         500 GRAIN FRAG   0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.00    0.00
                        1000 GRAIN FRAG   0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.00
   1050         0.15      30 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         120 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         500 GRAIN FRAG   0.01    0.02    0.02    0.02    0.02    0.02    0.01    0.01    0.01    0.00
                        1000 GRAIN FRAG   0.02    0.03    0.03    0.02    0.02    0.02    0.02    0.01    0.01    0.00
   1060         0.01                      VULNERABLE AREA IS EQUAL TO ZERO
   1080         0.13      30 GRAIN FRAG   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                         120 GRAIN FRAG   0.00    0.11    0.10    0.10    0.06    0.04    0.03    0.01    0.01    0.03
                         500 GRAIN FRAG   0.13    0.13    0.13    0.12    0.13    0.13    0.06    0.05    0.04    0.07
                        1000 GRAIN FRAG   0.13    0.13    0.13    0.12    0.13    0.13    0.13    0.07    0.05    0.05
   1150         0.05                      VULNERABLE AREA IS EQUAL TO ZERO
   1160         0.00                      VULNERABLE AREA IS EQUAL TO ZERO
   1170         0.06                      VULNERABLE AREA IS EQUAL TO ZERO
   1190         0.13      30 GRAIN FRAG   0.00    0.00    0.01    0.00    0.01    0.01    0.00    0.00    0.00    0.00
                         120 GRAIN FRAG   0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.02    0.01
                         500 GRAIN FRAG   0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.02
                        1000 GRAIN FRAG   0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
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Table 12: Results Of COVART Assessment Of Viper : 90°Azimuth, 0°Elevation (Continued)

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                                                                                                  COVART 3

    ATTACK ASPECT =  90 DEGREES AZIMUTH,    0 DEGREES ELEVATION

COMPONENT     PRESENTED     THREAT                                  SPEED (FEET PER SECOND)
  NAME          AREA                   3000   5000   7000   8000   9000  10000  11000  12000  13000  15000

 1220          1.06      30 GRAIN FRAG  0.87   0.92   0.93   0.94   0.95   0.96   0.96   0.97   0.97   0.97
                        120 GRAIN FRAG  0.92   0.95   0.97   0.97   0.97   0.97   0.98   0.99   0.99   0.99
                        500 GRAIN FRAG  0.92   0.97   0.99   0.99   0.99   0.99   0.99   0.99   0.99   0.99
                       1000 GRAIN FRAG  0.95   0.97   0.99   0.99   0.99   0.99   0.99   0.99   0.99   0.99
 1340          0.03                        VULNERABLE AREA IS EQUAL TO ZERO
 1350          0.10      30 GRAIN FRAG  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
                        120 GRAIN FRAG  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
                        500 GRAIN FRAG  0.00   0.09   0.10   0.10   0.07   0.04   0.03   0.02   0.03   0.02
                       1000 GRAIN FRAG  0.05   0.10   0.10   0.10   0.10   0.09   0.07   0.06   0.02   0.03
 1390          0.13      30 GRAIN FRAG  0.11   0.11   0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12
                        120 GRAIN FRAG  0.11   0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12
                        500 GRAIN FRAG  0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12
                       1000 GRAIN FRAG  0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12   0.12

 1400          0.10      30 GRAIN FRAG  0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10
                        120 GRAIN FRAG  0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10
                        500 GRAIN FRAG  0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10
                       1000 GRAIN FRAG  0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10
 1410          0.28      30 GRAIN FRAG  0.00   0.04   0.04   0.04   0.04   0.04   0.04   0.04   0.04   0.04
                        120 GRAIN FRAG  0.03   0.05   0.05   0.06   0.06   0.07   0.07   0.07   0.08   0.07
                        500 GRAIN FRAG  0.04   0.07   0.10   0.10   0.11   0.11   0.12   0.13   0.14   0.14
                       1000 GRAIN FRAG  0.04   0.08   0.13   0.14   0.15   0.16   0.16   0.16   0.16   0.16
 1420          0.06      30 GRAIN FRAG  0.00   0.01   0.01   0.01   0.00   0.01   0.01   0.01   0.00   0.01
                        120 GRAIN FRAG  0.01   0.02   0.02   0.02   0.02   0.02   0.02   0.02   0.02   0.01
                        500 GRAIN FRAG  0.01   0.02   0.03   0.03   0.03   0.03   0.03   0.03   0.02   0.02
                       1000 GRAIN FRAG  0.02   0.03   0.03   0.03   0.03   0.03   0.03   0.03   0.02   0.02
 1440          0.10      30 GRAIN FRAG  0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.10   0.10   0.10
                        120 GRAIN FRAG  0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09
                        500 GRAIN FRAG  0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09
                       1000 GRAIN FRAG  0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09   0.09
 1450          0.04      30 GRAIN FRAG  0.00   0.01   0.01   0.01   0.01   0.01   0.00   0.01   0.00   0.00
                        120 GRAIN FRAG  0.02   0.02   0.02   0.02   0.02   0.02   0.03   0.03   0.03   0.02
                        500 GRAIN FRAG  0.02   0.02   0.02   0.02   0.02   0.02   0.02   0.02   0.02   0.02
                       1000 GRAIN FRAG  0.02   0.02   0.02   0.02   0.02   0.02   0.02   0.02   0.02   0.02
 1460          0.06      30 GRAIN FRAG  0.02   0.03   0.03   0.03   0.03   0.03   0.03   0.03   0.03   0.03
                        120 GRAIN FRAG  0.03   0.03   0.03   0.03   0.03   0.03   0.03   0.03   0.03   0.03
                        500 GRAIN FRAG  0.03   0.03   0.04   0.03   0.03   0.03   0.03   0.03   0.03   0.03
                       1000 GRAIN FRAG  0.03   0.03   0.03   0.04   0.04   0.04   0.03   0.03   0.03   0.03
 1470          0.00                        VULNERABLE AREA IS EQUAL TO ZERO
 1550          2.06      30 GRAIN FRAG  0.01   0.06   0.05   0.05   0.04   0.04   0.03   0.03   0.02   0.02
                        120 GRAIN FRAG  0.05   0.05   0.05   0.05   0.06   0.07   0.07   0.06   0.06   0.06
                        500 GRAIN FRAG  0.05   0.06   0.06   0.06   0.06   0.07   0.08   0.09   0.09   0.08
                       1000 GRAIN FRAG  0.05   0.05   0.06   0.07   0.06   0.06   0.06   0.07   0.08   0.09
 3010          0.33                        VULNERABLE AREA IS EQUAL TO ZERO
 3020          0.33                        VULNERABLE AREA IS EQUAL TO ZERO
 3030          0.33                        VULNERABLE AREA IS EQUAL TO ZERO
 3040          0.33                        VULNERABLE AREA IS EQUAL TO ZERO
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Table 12: Results Of COVART Assessment Of Viper : 90°Azimuth, 0°Elevation (Continued)

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                                                                                                  COVART 3


      ATTACK ASPECT =  90 DEGREES AZIMUTH,   0 DEGREES ELEVATION

  COMPONENT      PRESENTED     THREAT                                SPEED (FEET PER SECOND)
    NAME           AREA                       3000    5000    7000    8000    9000   10000   11000   12000   13000   15000


    3110           0.01                          VULNERABLE AREA IS EQUAL TO ZERO
    3120           0.01                          VULNERABLE AREA IS EQUAL TO ZERO
    3130           0.02                          VULNERABLE AREA IS EQUAL TO ZERO
    3140           0.02                          VULNERABLE AREA IS EQUAL TO ZERO
    3210           0.09                          VULNERABLE AREA IS EQUAL TO ZERO
    3220           0.09                          VULNERABLE AREA IS EQUAL TO ZERO
    3230           0.10                          VULNERABLE AREA IS EQUAL TO ZERO
    3240           0.10                          VULNERABLE AREA IS EQUAL TO ZERO
    3310           0.01                          VULNERABLE AREA IS EQUAL TO ZERO
    3320           0.01                          VULNERABLE AREA IS EQUAL TO ZERO
    3330           0.09                          VULNERABLE AREA IS EQUAL TO ZERO
    3340           0.09                          VULNERABLE AREA IS EQUAL TO ZERO
    5120           1.39      30 GRAIN FRAG    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                            120 GRAIN FRAG    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                            500 GRAIN FRAG    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                           1000 GRAIN FRAG    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.05
    5130           0.05                          VULNERABLE AREA IS EQUAL TO ZERO
    5140           0.23                          VULNERABLE AREA IS EQUAL TO ZERO
    5210           0.01                          VULNERABLE AREA IS EQUAL TO ZERO
    5220           0.01                          VULNERABLE AREA IS EQUAL TO ZERO
    5230           0.00                          VULNERABLE AREA IS EQUAL TO ZERO
    5240           0.00                          VULNERABLE AREA IS EQUAL TO ZERO
    6100           0.06      30 GRAIN FRAG    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
                            120 GRAIN FRAG    0.01    0.01    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02
                            500 GRAIN FRAG    0.02    0.02    0.03    0.03    0.03    0.02    0.02    0.02    0.02    0.02
                           1000 GRAIN FRAG    0.02    0.03    0.03    0.03    0.03    0.03    0.02    0.02    0.02    0.02
    6110           0.03      30 GRAIN FRAG    0.00    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02    0.02
                            120 GRAIN FRAG    0.02    0.02    0.02    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                            500 GRAIN FRAG    0.02    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                           1000 GRAIN FRAG    0.02    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
    6120           0.03      30 GRAIN FRAG    0.00    0.01    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                            120 GRAIN FRAG    0.02    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                            500 GRAIN FRAG    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
                           1000 GRAIN FRAG    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
    6130           0.03                          VULNERABLE AREA IS EQUAL TO ZERO
    6150           0.15      30 GRAIN FRAG    0.05    0.09    0.10    0.10    0.10    0.10    0.10    0.10    0.10    0.10
                            120 GRAIN FRAG    0.08    0.13    0.13    0.13    0.14    0.14    0.14    0.14    0.13    0.13
                            500 GRAIN FRAG    0.14    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.14
                           1000 GRAIN FRAG    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15
    6500           0.23      30 GRAIN FRAG    0.00    0.14    0.15    0.19    0.19    0.19    0.19    0.19    0.19    0.18
                            120 GRAIN FRAG    0.14    0.20    0.20    0.20    0.20    0.20    0.20    0.20    0.20    0.20
                            500 GRAIN FRAG    0.17    0.20    0.20    0.20    0.20    0.20    0.20    0.20    0.20    0.20
                           1000 GRAIN FRAG    0.17    0.20    0.20    0.20    0.20    0.20    0.20    0.20    0.20    0.20
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Table 12: Results Of COVART Assessment Of Viper : 90°Azimuth, 0°Elevation (Continued)

COVART 3

ATTACK ASPECT = 90 DEGREES AZIMUTH, 0 DEGREES ELEVATION

COMPONENT NAME	PRESENTED AREA	THREAT	SPEED (FEET PER SECOND) 3000	5000	7000	8000	9000	10000	11000	12000	13000	15000
6510	0.06	30 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		120 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		500 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		1000 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6550	0.31	30 GRAIN FRAG	0.00	0.20	0.25	0.26	0.26	0.27	0.27	0.27	0.27	0.26
		120 GRAIN FRAG	0.21	0.27	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29
		500 GRAIN FRAG	0.24	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
		1000 GRAIN FRAG	0.25	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
6560	0.13	30 GRAIN FRAG	0.08	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
		120 GRAIN FRAG	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13
		500 GRAIN FRAG	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
		1000 GRAIN FRAG	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
6610	0.03	30 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		120 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		500 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		1000 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
6620	0.03	30 GRAIN FRAG	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
		120 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
		500 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		1000 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6630	0.35	30 GRAIN FRAG	0.00	0.28	0.31	0.34	0.34	0.34	0.34	0.34	0.33	0.32
		120 GRAIN FRAG	0.25	0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
		500 GRAIN FRAG	0.29	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
		1000 GRAIN FRAG	0.30	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
6640	0.12	30 GRAIN FRAG	0.00	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.10
		120 GRAIN FRAG	0.08	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
		500 GRAIN FRAG	0.10	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
		1000 GRAIN FRAG	0.10	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
6650	0.03	30 GRAIN FRAG	0.00	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		120 GRAIN FRAG	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		500 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		1000 GRAIN FRAG	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
6660	0.68	30 GRAIN FRAG	0.00	0.56	0.63	0.66	0.66	0.66	0.66	0.66	0.66	0.64
		120 GRAIN FRAG	0.49	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
		500 GRAIN FRAG	0.57	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
		1000 GRAIN FRAG	0.58	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
6670	0.43	30 GRAIN FRAG	0.11	0.26	0.28	0.28	0.29	0.29	0.29	0.30	0.30	0.30
		120 GRAIN FRAG	0.25	0.32	0.34	0.35	0.35	0.35	0.36	0.36	0.36	0.36
		500 GRAIN FRAG	0.33	0.36	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
		1000 GRAIN FRAG	0.36	0.37	0.37	0.37	0.37	0.37	0.38	0.38	0.39	0.40
6680	0.49	30 GRAIN FRAG	0.11	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
		120 GRAIN FRAG	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16
		500 GRAIN FRAG	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
		1000 GRAIN FRAG	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Table 12: Results Of COVART Assessment Of Viper : 90°Azimuth, 0°Elevation (Continued)

ATTACK ASPECT = 90 DEGREES AZIMUTH, 0 DEGREES ELEVATION

COMPONENT NAME	PRESENTED AREA	THREAT	SPEED (FEET PER SECOND)									
			3000	5000	7000	8000	9000	10000	11000	12000	13000	15000
8100	0.38	30 GRAIN FRAG	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
		120 GRAIN FRAG	0.05	0.08	0.11	0.13	0.14	0.15	0.16	0.17	0.17	0.17
		500 GRAIN FRAG	0.12	0.18	0.23	0.24	0.25	0.26	0.26	0.27	0.27	0.26
		1000 GRAIN FRAG	0.18	0.23	0.25	0.27	0.28	0.28	0.28	0.29	0.29	0.28
8150	0.17	30 GRAIN FRAG	0.12	0.08	0.06	0.05	0.01	0.01	0.00	0.00	0.00	0.01
		120 GRAIN FRAG	0.12	0.14	0.13	0.13	0.13	0.09	0.11	0.04	0.04	0.01
		500 GRAIN FRAG	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.08
		1000 GRAIN FRAG	0.13	0.13	0.14	0.13	0.14	0.13	0.13	0.13	0.12	0.09
4100	0.03		VULNERABLE AREA IS EQUAL TO ZERO									
4110	0.30	30 GRAIN FRAG	0.27	0.27	0.23	0.17	0.15	0.13	0.12	0.10	0.08	0.05
		120 GRAIN FRAG	0.27	0.28	0.30	0.30	0.30	0.29	0.28	0.28	0.28	0.28
		500 GRAIN FRAG	0.28	0.30	0.30	0.30	0.30	0.30	0.29	0.29	0.29	0.28
		1000 GRAIN FRAG	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.29	0.29	0.29
4120	0.18	30 GRAIN FRAG	0.18	0.18	0.10	0.09	0.08	0.07	0.06	0.04	0.03	0.01
		120 GRAIN FRAG	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
		500 GRAIN FRAG	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
		1000 GRAIN FRAG	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
4130	0.24	30 GRAIN FRAG	0.22	0.22	0.13	0.11	0.09	0.08	0.06	0.04	0.02	0.01
		120 GRAIN FRAG	0.22	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.22
		500 GRAIN FRAG	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
		1000 GRAIN FRAG	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
4140	0.25	30 GRAIN FRAG	0.23	0.23	0.13	0.11	0.09	0.07	0.05	0.02	0.00	0.02
		120 GRAIN FRAG	0.23	0.25	0.25	0.25	0.25	0.25	0.24	0.23	0.23	0.15
		500 GRAIN FRAG	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24
		1000 GRAIN FRAG	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
4150	0.25	30 GRAIN FRAG	0.24	0.20	0.12	0.10	0.08	0.06	0.04	0.01	0.03	0.03
		120 GRAIN FRAG	0.24	0.25	0.25	0.25	0.25	0.25	0.24	0.24	0.24	0.07
		500 GRAIN FRAG	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24
		1000 GRAIN FRAG	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
4160	0.28	30 GRAIN FRAG	0.24	0.20	0.13	0.11	0.08	0.06	0.03	0.03	0.05	0.04
		120 GRAIN FRAG	0.26	0.28	0.28	0.28	0.28	0.26	0.25	0.24	0.25	0.09
		500 GRAIN FRAG	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.27
		1000 GRAIN FRAG	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.27
4170	0.24	30 GRAIN FRAG	0.22	0.16	0.11	0.09	0.07	0.05	0.02	0.02	0.04	0.03
		120 GRAIN FRAG	0.24	0.24	0.24	0.24	0.24	0.22	0.22	0.22	0.22	0.09
		500 GRAIN FRAG	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.23
		1000 GRAIN FRAG	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.23
4180	0.24	30 GRAIN FRAG	0.23	0.17	0.11	0.09	0.07	0.05	0.02	0.01	0.03	0.02
		120 GRAIN FRAG	0.24	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.09
		500 GRAIN FRAG	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.23
		1000 GRAIN FRAG	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.23
4190	0.26	30 GRAIN FRAG	0.23	0.18	0.12	0.10	0.08	0.05	0.03	0.03	0.05	0.05
		120 GRAIN FRAG	0.26	0.26	0.26	0.26	0.26	0.24	0.23	0.23	0.23	0.08
		500 GRAIN FRAG	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25
		1000 GRAIN FRAG	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25
4200	0.20	30 GRAIN FRAG	0.19	0.16	0.10	0.08	0.06	0.05	0.03	0.01	0.02	0.03
		120 GRAIN FRAG	0.19	0.20	0.20	0.20	0.20	0.20	0.19	0.19	0.19	0.06
		500 GRAIN FRAG	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
		1000 GRAIN FRAG	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
4210	0.27	30 GRAIN FRAG	0.24	0.24	0.14	0.12	0.10	0.07	0.05	0.03	0.00	0.03
		120 GRAIN FRAG	0.24	0.27	0.27	0.27	0.27	0.27	0.26	0.25	0.24	0.14
		500 GRAIN FRAG	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.26
		1000 GRAIN FRAG	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27

Table 12: Results Of COVART Assessment Of Viper : 90°Azimuth, 0°Elevation (Continued)

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                                                                                                    COVART 3


     ATTACK ASPECT =  90 DEGREES AZIMUTH,    0 DEGREES ELEVATION

COMPONENT    PRESENTED    THREAT                                 SPEED (FEET PER SECOND)
  NAME         AREA                       3000   5000   7000   8000   9000  10000  11000  12000  13000  15000

 4220          0.19      30 GRAIN FRAG    0.19   0.19   0.10   0.09   0.08   0.06   0.05   0.03   0.02   0.01
                        120 GRAIN FRAG    0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19
                        500 GRAIN FRAG    0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19
                       1000 GRAIN FRAG    0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19   0.19
 4230          0.26      30 GRAIN FRAG    0.23   0.23   0.15   0.13   0.12   0.10   0.08   0.06   0.04   0.01
                        120 GRAIN FRAG    0.23   0.26   0.26   0.26   0.26   0.26   0.26   0.26   0.26   0.26
                        500 GRAIN FRAG    0.26   0.26   0.26   0.26   0.26   0.26   0.26   0.26   0.26   0.26
                       1000 GRAIN FRAG    0.26   0.26   0.26   0.26   0.26   0.26   0.26   0.26   0.26   0.26
 4240          0.33      30 GRAIN FRAG    0.31   0.31   0.27   0.20   0.17   0.15   0.13   0.11   0.10   0.06
                        120 GRAIN FRAG    0.31   0.31   0.33   0.33   0.32   0.32   0.31   0.31   0.31   0.31
                        500 GRAIN FRAG    0.31   0.33   0.33   0.33   0.33   0.33   0.32   0.32   0.32   0.31
                       1000 GRAIN FRAG    0.33   0.33   0.33   0.33   0.33   0.33   0.33   0.32   0.32   0.32
 4250          0.18      30 GRAIN FRAG    0.17   0.17   0.17   0.17   0.15   0.12   0.10   0.09   0.08   0.06
                        120 GRAIN FRAG    0.17   0.17   0.17   0.18   0.17   0.17   0.17   0.17   0.17   0.17
                        500 GRAIN FRAG    0.17   0.18   0.18   0.18   0.17   0.17   0.17   0.17   0.17   0.17
                       1000 GRAIN FRAG    0.17   0.18   0.18   0.18   0.18   0.17   0.17   0.17   0.17   0.17


     SINGLE SHOT VULNERABLE AREAS OF MULTIPLY-VULNERABLE GROUPS (SQUARE FEET)
          (THESE RESULTS ARE INCLUDED IN THE TOTAL TARGET VULNERABLE AREAS)

      KILL        GROUP    PRESENTED    THREAT                                 SPEED (FEET PER SECOND)
    CATEGORY      NAME       AREA                       3000   5000   7000   8000   9000  10000  11000  12000  13000  15000

    KILL 1       CONTROL     0.92      30 GRAIN FRAG    0.01   0.02   0.01   0.01   0.01   0.01   0.01   0.01   0.01   0.01
                                      120 GRAIN FRAG    0.02   0.05   0.06   0.06   0.07   0.07   0.06   0.06   0.06   0.05
                                      500 GRAIN FRAG    0.08   0.10   0.12   0.13   0.14   0.13   0.13   0.12   0.12   0.11
                                     1000 GRAIN FRAG    0.09   0.12   0.14   0.15   0.15   0.14   0.14   0.14   0.13   0.14
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Table 12: Results Of COVART Assessment Of Viper : 90°Azimuth, 0°Elevation (Continued)

COVART 3

SYSTEM MULTIPLY VULNERABLE AREAS (SQUARE FEET) FOR KILL 1 MISSION

COMPONENT NAME	PRESENTED AREA	THREAT	SPEED (FEET PER SECOND) 3000	5000	7000	8000	9000	10000	11000	12000	13000	15000
UPPORT	0.42	30 GRAIN FRAG	0.00	0.05	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.01
		120 GRAIN FRAG	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		500 GRAIN FRAG	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		1000 GRAIN FRAG	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
UPSTAR	0.42	30 GRAIN FRAG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		120 GRAIN FRAG	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		500 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
		1000 GRAIN FRAG	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
LOPORT	0.51	30 GRAIN FRAG	0.05	0.11	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.07
		120 GRAIN FRAG	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13
		500 GRAIN FRAG	0.10	0.08	0.08	0.08	0.09	0.10	0.11	0.11	0.12	0.13
		1000 GRAIN FRAG	0.11	0.06	0.06	0.06	0.06	0.08	0.10	0.11	0.11	0.11
LOSTAR	0.51	30 GRAIN FRAG	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		120 GRAIN FRAG	0.00	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01
		500 GRAIN FRAG	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.02
		1000 GRAIN FRAG	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02

Conclusions

The vulnerability of cruise missiles has been examined using the Systems Engineering Process and Vulnerability Analysis programs. The Definition of Need for vulnerability analysis was presented. Functional Analysis gave insight into how cruise missiles are arranged and operate. Failure Analysis addressed how these systems could be defeated. Finally, the Vulnerability Analysis took into account the physical characteristics and the results of the Systems Engineering Process to provide an estimate of overall system vulnerability.

Although the target evaluated in this report is generic, the process followed would work equally well for other cruise missile systems. In fact, the principles of identifying needs, defining functions and evaluating failure modes could be applied to the analysis of most any type of system.

In the future, analysts need to remain aware of trends in the design of cruise missiles, and the methods needed to defeat them. Fragmenting warheads continue to evolve, yet the analyst should not limit their efforts to this method. Advances are being made in fields such as ballistics, flight dynamics, and explosive physics. Application of these advances, made possible by greater computational capabilities, would allow for more detailed and, presumably, more accurate vulnerability models.

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