MISSILE DEFENSE AGENCY

DIRECTORATE OF COST ESTIMATING AND ANALYSIS

WHITE PAPER

Kill Vehicle Work Breakdown Structure

Abstract:

This paper provides a proposal for an alternative to Appendix C Missile Systems for inclusion in MIL-STD-881C, the Department of Defense standard for Work Breakdown Structures (WBSs). The Missile Defense Agency (MDA) produces interceptors that are similar to missiles with the exception of the payload element. Where Appendix C defines the payload element with a limited set of WBS elements, the MDA interceptor payload, referred to as a kill vehicle, includes a large collection of significant WBS elements. A kill vehicle is a guided weapon that utilizes hit-to-kill technology after separation from a boosting vehicle. Described as "hitting a bullet with a bullet" its purpose is the destruction of a ballistic missile threat and/or a threat re-entry vehicle. MDA's kill vehicles do not contain any explosives; instead the kill vehicles use kinetic energy from the engagement velocities to provide the destructive forces. Additionally, MDA kill vehicles operate autonomously as short lived space vehicles. Based on the number of significant WBS elements for MDA kill vehicles, it is determined that the current MIL-STD-881C Appendix C Missile Systems Payload WBS is insufficient. An analysis of MDA's currently produced kill vehicles; Ground-Based Midcourse Defense "Exo-atmospheric Kill Vehicle," Aegis Ballistic Missile Defense "Kinetic Warhead," and Terminal High Altitude Area Defense "Kill Vehicle", was done to establish commonality. As a result, MDA/DOC created three alternatives based on Appendix F Space Systems WBS and Appendix C Missile Systems WBS from MIL-STD-881C. The proposed KV WBS, a hybrid of Appendix F and Appendix C, will support existing and future kill vehicle designs.

1. PURPOSE

The Missile Defense Agency (MDA) Directorate for Cost Estimating and Analysis (DOC) proposes and seeks approval for a Kill Vehicle (KV) Work Breakdown Structure (WBS) consistent with Military Standard 881C (MIL-STD-881C). MIL-STD-881C is the standard approved for Department of Defense (DoD) departments and agencies. This standard contains WBSs for many products, including but not limited to, missiles, launch vehicles, and space vehicles, yet MIL-STD-881C does not address kill vehicles. This paper presents a KV WBS that is derived from MIL-STD-881C and is tailored for MDA kill vehicles. This is part of a larger effort to integrate MDA cost data with the overall DoD Defense Automated Cost Information

Management System (DACIMS) database maintained by the Office of the Secretary of Defense (OSD) – Cost Assessment and Program Evaluation (CAPE) Defense Cost and Resource Center (DCARC).

2. BACKGROUND

The National Missile Defense Act (NMDA) states it is the policy of the United States to deploy, as soon as is technologically possible, an effective National Missile Defense system capable of defending the territory of the United States against limited ballistic missile attack (whether accidental, unauthorized, or deliberate) with funding subject to the annual authorization of appropriations and the annual appropriation of funds for National Missile Defense. The mission of MDA is to develop, test, and field an integrated, layered, Ballistic Missile Defense System (BMDS) to defend the United States, its deployed forces, allies, and friends against all ranges of enemy ballistic missiles in all phases of flight. MDA's strategic goals include: supporting the warfighter, proving the power of missile defense through testing, continuing the development and fielding of the integrated BMDS for homeland and regional defense, optimize available resources to name a few.

The urgency of the NMDA historically placed emphasis on fielding these capabilities; consequently MDA did not focus attention on supplying cost data to the DoD DCARC. In 2012, MDA Director for Operations instructed MDA/DOC Director to extend support to DCARC to ensure inclusion of future MDA cost data in the DoD DACIMS database. In particular, this support requires MDA/DOC to work with DCARC on Contractor Cost Data Reporting which is heavily dependent on a standard WBS. As part of this compliance effort, MDA/DOC identified kill vehicles as the primary product MIL-STD-881C does not address. MDA's effort to form a KV WBS consistent with MIL-STD-881C will support data collection across MDA kill vehicle programs.

MIL-STD-881C contains a Missile Systems WBS where a modern missile is defined as a self-propelled guided weapon system having four system components: targeting and/or guidance, flight system, engine, and payload. The payload generally contains one or more explosive warheads. The warhead(s) of a missile provides its primary destructive power (many missiles have extensive secondary destructive power due to the high kinetic energy of the weapon and unburnt fuel that may be on board). Warheads are most commonly high explosives, often employing shaped charges to exploit the accuracy of a guided weapon to destroy hardened targets which are usually stationary or slow moving.

Unlike the described warheads, MDA's kill vehicles do not contain any explosives and instead use the kinetic energy of the engagement velocities to provide the destructive forces. This eliminates the need for the kill vehicles to contain explosives. Additionally, MDA kill vehicles operate autonomously as short lived space vehicles. For these reasons, the current MIL-STD-881C Appendix C Missile Systems Payload WBS is insufficient for MDA kill vehicle needs.

This paper provides descriptions of each MDA kill vehicle and different alternatives to establish commonality for kill vehicles across the Agency. The result is the proposal of an alternate Appendix C for inclusion in MIL-STD-881C. The proposed KV WBS will support existing and future kill vehicle technologies.

3. KILL VEHICLES

The kill vehicle system is the complex of hardware, software, data, services, and facilities necessary to develop and produce a mechanism to detect and defeat ballistic missile threats. A kill vehicle is a guided weapon that utilizes hit-to-kill technology after separation from a boosting vehicle. Its purpose is the destruction of a ballistic missile threat and/or a threat re-entry vehicle described as "hitting a bullet with a bullet." Currently, MDA produces the Ground-Based Midcourse Defense "Exo-atmospheric Kill Vehicle," Aegis Ballistic Missile Defense "Kinetic Warhead," and Terminal High Altitude Area Defense "Kill Vehicle."

3.1. GROUND-BASED MIDCOURSE DEFENSE – "EXO-ATMOSPHERIC KILL VEHICLE"

The Ground-Based Interceptor (GBI) is a multi-stage, solid fuel booster with an Exo-atmospheric Kill Vehicle (EKV) payload. It has the capability to engage and destroy limited intermediate- and long-range ballistic missile threats in space. The EKV utilizes hit-to-kill technology that flies autonomously once it separates from the missile body/booster. The EKV consists of an advanced multi-color sensor, independent liquid propellant divert and attitude control system (DACS), communications link, discrimination algorithms, guidance and control system, and computers to support threat selection and intercept. After launch, the booster carries the EKV toward the threat's predicted location in space. Once separation from the booster occurs, the EKV uses guidance transmitted from Ground Support & Fire Control System components and on-board sensors to close with and destroy the threat. The impact is outside the Earth's atmosphere.

3.2. AEGIS BALLISTIC MISSILE DEFENSE – "KINETIC WARHEAD"

The Standard Missile-3 (SM-3), a defensive weapon used by the U.S. Navy, is a multi-stage, solid fuel booster with a Kinetic Warhead (KW) payload. It has the capability to engage and

destroy short- to intermediate-range, unitary and separating, midcourse-phase ballistic missile threats. The KW utilizes hit-to-kill technology that flies autonomously once it separates from the missile body/booster. The KW consists of an advanced discrimination seeker, solid propellant DACS, advanced signal processor, and nosecone. After launch, the booster carries the KW toward the threat's predicted location in space. Once separation from the booster occurs, the KW uses guidance transmitted from the Navy's Aegis Ballistic Missile Defense System components and on-board sensors to close with and destroy the threat. The impact is outside the Earth's atmosphere.

3.3. TERMINAL HIGH ALTITUDE AREA DEFENSE – "KILL VEHICLE"

The Terminal High Altitude Area Defense (THAAD) is a defensive weapon system used by the U.S. Army. It utilizes a missile which consists of a solid fuel booster with a Kill Vehicle (KV) payload. It has the capability to engage and destroy ballistic missiles inside or outside the atmosphere during the final or terminal phase of flight. The THAAD KV utilizes hit-to-kill technology that flies autonomously once it separates from the missile body/booster. The KV consists of a shroud, fore-cone, seeker, liquid propellant DACS, and guidance and control electronics. The KV has an uncooled sapphire window with an infrared seeker mounted on a two-axis stabilized platform. After launch, the booster carries the KV toward the threat's predicted location in space. Once released from the booster, the KV uses data transmitted from Army Navy/Transportable Radar Surveillance components and on-board sensors to close with and destroy the threat. The impact can occur inside or outside the Earth's atmosphere.

3.4. COMPARISON OF KILL VEHICLES

Each Agency kill vehicle is uniquely designed; with differences in areas that include: terminology, placement, dictionaries, grouping, and sub-elements. These differences present challenges in developing a KV WBS comparison across the programs. For example, distinctive terminology exists even at the system level; where the Agency provides unique names for its kill vehicles (i.e., "Exo-atmospheric Kill Vehicle," "Kinetic Warhead," and "Kill Vehicle"). In general, the kill vehicles share functions in common; however characteristics and terminology differ depending on the specific kill vehicle. For this proposal, MDA/DOC develops a crosswalk between EKV, KW, and KV to help align the nomenclature differences.

The resulting comparison identifies certain high level elements as having the same function. For example, the seeker and guidance computer both operate in guiding the kill vehicle. For this reason, the guidance element will contain both of these sub-elements. Additionally, the

comparison determines which elements to omit from the initial KV WBS and define in the dictionary; the end result is a comprehensive WBS with fewer elements which can represent any current or future proposed MDA kill vehicles.

4. DEVELOPING KV WBS ALTERNATIVES CONSISTENT WITH MIL-STD-881C

The next step is to develop a KV WBS that is consistent with MIL-STD-881C. The initial KV WBS is a simple blending of the program WBSs and serves as the starting point for developing the proposed KV WBS. MDA/DOC presents three alternatives for creating this new MIL-STD-881C KV WBS. The initial KV WBS will assist with accepting or rejecting these different alternatives.

4.1. ALTERNATIVE I – SIMPLIFIED SPACE SYSTEMS WBS

Alternative I derives the KV WBS from MIL-STD-881C Appendix F Space Systems. This appendix provides the WBS and definitions for space vehicles. This alternative uses Appendix F to model the kill vehicle from the space vehicle and model the boosting system from the launch vehicle; creating a simplified version of the Space Systems WBS.

The advantage of Alternative I is the kill vehicle and space vehicle possess similar sub-elements. These sub-elements include: attitude control system, star tracker, global positioning system receivers, antennas, cryogenic devices, inertial measurement units, and a focal plane array. The launch vehicle represents the boosting system and is predefined by MIL-STD-881C Appendix F. The KV WBS evolves from the space vehicle WBS which defines essential kill vehicle sub-elements and presents a clear trace to the existing MIL-STD-881C.

Alternative I has several significant drawbacks. The first is the Space Systems WBS includes many extraneous elements such as: ground operations, ground terminal, external network, facilities, vehicles, shelters, insurance, and orbital transfer vehicle. In addition, space vehicles sustain exo-atmospheric conditions ranging from days, weeks, or years; while kill vehicles may only operate in space for minutes. Subsystems required to support the space vehicle in these conditions include sub-elements unnecessary to the kill vehicle, such as: torsion rods, solar arrays, magnetometers, spectrometer, altitude control wheels, heating and cooling thermal controls systems, and earth/sun sensors. Also, there are nomenclature differences that are atypical in the kill vehicle community. For example, the WBS for space vehicles refers to Pointing, Command, and Control Interface (PCCI) and Telemetry, Tracking and Command (TTC) functions whereas kill vehicle nomenclature refers to these functions as guidance, navigation, and communications.

4.2. ALTERNATIVE II – MISSILE WITHIN MISSILE SYSTEMS WBS

Alternative II derives the KV WBS from MIL-STD-881C Appendix C Missile Systems. This appendix provides the WBS and definitions for missile systems. In general, missiles fall into a range of categories: from tactical air-to-air missiles to strategic ballistic missiles. MIL-STD-881C covers all these categories. MDA's GBI, SM-3, and THAAD are ballistic missiles. This alternative uses Appendix C to model both the kill vehicle and boosting system with the air vehicle WBS. This creates a missile within a missile version of the Missile Systems WBS. That is, the kill vehicle becomes the payload of a ballistic missile represented by the Missile Systems WBS in MIL-STD-881C Appendix C.

The advantage of Alternative II is the kill vehicle and air vehicle possess similar elements. These elements include: propulsion, power and distribution, guidance, navigation, and communications. The air vehicle represents the boosting system and is predefined by MIL-STD-881C Appendix C. The kill vehicle evolves from the air vehicle which defines essential kill vehicle elements and presents a clear trace to the existing MIL-STD-881C.

Alternative II has several significant drawbacks. The first is the Missile Systems WBS includes many extraneous elements such as: an encasement device, command and launch, training and data, and industrial facilities. In addition to the system level elements, the air vehicle contains unnecessary sub-elements such as: airframe, arm/fire device, dome assembly, fin/canard deployment, and actuators. Additionally, the air vehicle lacks sub-elements such as star trackers, global positioning system receivers, cryogenic devices, and sun shades which are essential sub-elements to kill vehicles. While the air vehicle WBS possesses elements essential to kill vehicles, the payload WBS needs to include many sub-elements for the kill vehicle to map to the air vehicle.

4.3. ALTERNATIVE III – PROPOSED HYBRID WBS

Alternative III, the proposed Hybrid KV WBS, derives from MIL-STD-881C Appendix F Space Systems and Appendix C Missile Systems. This alternative defines both the booster and the kill vehicle using the air vehicle from Appendix C; then combines space vehicle elements from Appendix F to form a hybrid KV WBS with corresponding dictionary. The proposed KV WBS numbering will begin with Appendix C WBS 1.1.8 Payload and substitute the KV WBS. Below WBS 1.1.8, the proposed WBS alters the arrangement, modifies select elements, and defines new elements specific to kill vehicles (see attachment).

The advantages of Alternative III is that it leverages the best qualities of Alternatives I and II, traces to MIL-STD-881C, and develops a unique standalone solution to the kill vehicle WBS. The air vehicle represents the boosting system and is predefined by MIL-STD-881C Appendix C. The proposed KV WBS evolves from the air vehicle WBS defining essential kill vehicle elements and also traces to MIL-STD-881C. The kill vehicle and air vehicle possess similar elements including: propulsion, power and distribution, guidance, navigation, and communications. The kill vehicle sub-elements trace to the space vehicle sub-elements including: attitude control system, star tracker, global positioning system receivers, antennas, cryogenic devices, inertial measurement units, and a focal plane array.

Alternative III does have a few drawbacks. The combination of air vehicle elements and space vehicles elements is not always easy. Some of the disadvantages of Alternatives I and II remain and present problems for the hybrid approach; new definitions are required and the alignment of certain sub-elements becomes unique to the proposed KV WBS. An example is guidance and control processing. Guidance is originally a component of the air vehicle WBS; the modification reflects the nomenclature of the kill vehicle community. The seeker is a guiding element in the kill vehicle and becomes a sub-element of guidance and control processing. This is consistent with the air vehicle WBS. Additionally, the seeker WBS is not defined to the sub-element by either Appendix C or F, and requires a combination of new, modified, and reused elements and definitions to form a seeker WBS. These realigned, renamed, or newly defined elements become unique to the proposed KV WBS and will not trace easily to existing MIL-STD-881C.

Overall, the Alternative III advantages outweigh the drawbacks; as the foundation of the proposed Hybrid KV WBS traces largely to existing MIL-STD-881C appendices. The Missile Systems WBS functions as the backbone and the space vehicle WBS provides the details. The proposed KV WBS will be a substitute for the payload of the Appendix C Missile System WBS. The proposed KV WBS is representative of MDA current and proposed future kill vehicles.

5. CONCLUSION

This paper addresses the need for a WBS to represent the current and proposed future MDA kill vehicles. It gives an overview of the unique types of kill vehicles MDA develops and produces. During the development of the proposed KV WBS, MDA/DOC constructed a comparison of MDA kill vehicles in order to facilitate three alternatives based on MIL-STD-881C. MDA/DOC uses the hardware similarity, architecture, and usable elements to help evaluate the

alternatives. The proposed Alternative III KV WBS is an alternate to Appendix C and is recommended for inclusion in MIL-STD-881C.

ATTACHMENT:

ALTERNATE APPENDIX C

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APPENDIX C: ALTERNATIVE MISSILE SYSTEMS WITH KILL VEHICLE AS PAYLOAD WORK BREAKDOWN STRUCTURE AND DEFINITIONS

C.1 SCOPE

This appendix provides the Work Breakdown Structure and Definitions for missile systems. Definitions for WBS elements common to the missile system and all other defense materiel items are given in Appendix L: Common Elements, Work Breakdown Structure and Definitions.

C.2 APPLICABLE DOCUMENTS

C.2.1 Non-Government publications. The following documents form a part of this document to the extent specified herein.

MIL-STD-881C Missile System with Kill Vehicle

C.3 WORK BREAKDOWN STRUCTURE LEVELS

WBS#	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
1.1.8			Kill Vehicle			
1.1.8.1				Kill Vehicle Structure and Harnesses		
1.1.8.2				Divert and Attitude Control System (DACS)		
1.1.8.2.1					DACS Integration, Assembly, Test and Checkout	
1.1.8.2.2					Divert Subsystem	
1.1.8.2.3					Attitude Control System	
1.1.8.2.4					Gas Generator/Structure	
1.1.8.2.5					Controller Electronics	
1.1.8.2.6					Ordnance Initiation Set	
1.1.8.2.7					Flight Termination System	
1.1.8.2.8					DACS Software Release 1…n	
1.1.8.3				Power and Distribution		
1.1.8.3.1					Power and Distribution Integration, Assembly, Test and Checkout	
1.1.8.3.2					Primary Power	
1.1.8.3.3					Power Conditioning Electronics	
1.1.8.3.4					Distribution Harness	
1.1.8.3.5					Power and Distribution Software Release 1…n	
1.1.8.4				Guidance and Control Processing		
1.1.8.4.1					Guidance and Control Processing Integration, Assembly, Test and Checkout	
1.1.8.4.2					Seeker Assembly	
1.1.8.4.3.1						Seeker Integration, Assembly, Test and Checkout
1.1.8.4.3.2						Optical Telescope Assembly
1.1.8.4.3.3						Focal Plane Array
1.1.8.4.3.4						Cooling Assembly
1.1.8.4.3.5						Electronics
1.1.8.4.3.6						Gimbal Assembly
1.1.8.4.3.7						Seeker Software Release 1…n
1.1.8.4.3					Guidance Computer	
1.1.8.4.4					Guidance and Control Processing Software Release 1…n	
1.1.8.5				Navigation		
1.1.8.5.1					Navigation Integration, Assembly, Test and Checkout	
1.1.8.5.2					Sensor Assemblies	
1.1.8.5.3					Navigation Software Release 1…n	
1.1.8.6				Communications		
1.1.8.6.1					Communications Integration, Assembly, Test and Checkout	
1.1.8.6.2					Communications Subsystem	
1.1.8.6.3					Antenna Assembly	
1.1.8.6.4					Communications Software Release 1…n	
1.1.8.7				Reserved		
1.1.8.8				Kill Vehicle Integration, Assembly, Test and Checkout		
1.1.8.9				Systems Engineering		
1.1.8.10				Program Management		
1.1.8.11				System Test and Evaluation		
1.1.8.12				Peculiar Support Equipment		
1.1.8.13				Common Support Equipment		

C.3.1 Application of Common WBS Elements (Appendix L). WBS elements that are common (i.e., Integration, Assembly, Test and Checkout; Systems Engineering; Program Management; System Test and Evaluation; Training; and Data) should be applied to the appropriate levels within the WBS for which they support. For example, if Systems Engineering is required to support a Level 4 WBS element, the Systems Engineering WBS element would appear at Level 5 of the WBS under the Level 4 element it supports.

C.3.2 Key Principles in Constructing a WBS. In the appendices of MIL-STD-881C, the WBS is defined to Level 4 of that structure and in some cases Level 5 or 5. In order to ensure consistency across all systems and developers, WBS elements in the appendices are extended to levels 4 and 5.

1) The reporting level of the WBS is typically at Level 4 except for those items considered high cost, high risk, or high technical interest. For those elements, extension of the WBS to lower levels is necessary to get needed visibility, but only for those elements. Not all WBS elements should be extended to the lowest level. In addition, for each system being defined only those WBS elements that define the system shall be used. The purpose of going below Level 4 within the appendix is to ensure that the higher level elements include the proper lower level elements and when required to report at a lower level, those elements at Level 5 or 5 are consistent across all systems and developers.

2) In each of the appendices, an element entitled "Other" is available to provide flexibility within the WBS for new or additional WBS elements that are not identified or defined in the Standard. These "other" elements would be used if, for example, a new subsystem or modified subsystem is defined and it does not currently appear in the appendices of MIL-STD-881C.

3) A key to WBS development is the principle that if you can associate the WBS element with the element it supports, it should be included within that element. This is called the 100% rule, which states the next level of decomposition of a WBS element (child level) must represent 100% of the work applicable to the next higher level (parent level). For example, the parent level WBS (radar system) has three child elements - transmitter, antenna, and receiver. If the program manager decides he/she wants more visibility into the transmitter subsystem and pulls it out of the radar system and makes it a level equal to the radar, it distorts the effort and resources that are required to complete that radar system because it assumes the transmitter is not included (i.e., a child element to the radar is now missing within the WBS structure).

4) In some cases, items cannot be specifically associated with the element they support. For example, software is a critical element of that transmitter subsystem. Under normal circumstances, software would be the child level to the parent level transmitter. However, depending on how software is developed, the software may include more functionality than just for the transmitter subsystem. It may include functionality for the receiver as well. In this case the software cannot be associated with the specific elements they support, due to an inability to determine the effort for each functionality developed. Therefore, it is appropriate to associate that software to the next highest level (radar system) of the WBS. It is still included as a part of the radar system at the child level, but we are not trying to allocate effort across multiple WBS elements where we are unable to determine what level of support each gets.

5) Intelligence (Intel) efforts (security, threat, mission data) are often considered late in the acquisition cycle, even after contract award. Identifying where Intel is needed reduces risk and affords a much better opportunity to manage cost, schedule, and performance. The WBS Standard portrays systems in a product-oriented WBS, identifying and considering potential intelligence information and costs using the existing Component cost estimating processes.

C.3.3 Numbering of the WBS. In each appendix, the work breakdown structure for that commodity has been numbered for reporting purposes only. The purpose for the numbering is to provide a consistent approach to identifying and managing the WBS across like systems regardless of vendor or service. The numbering system is numeric; however, several unique issues arise across appendices which require the numbering system to be modified to accommodate the anomalies.

C.3.3.1. "Other" WBS Elements. All appendices contain a WBS element titled as "Other" at the subsystem, element (product) levels that are restricted for products that have not been envisioned or predicted within the defined WBS elements in the Appendix. If it is determined that the "other" WBS is not needed, this element and assigned WBS number should be deleted and not used in the WBS. If it is determined that the "other" element is needed, then each element must be defined and the word "other" replaced by the newly defined WBS element using the assigned WBS number from the appropriate appendix. The newly defined element must be approved by the Government Program Manager and the representative contracting officer.

C.3.3.2 (1…n) WBS Element Definitions. Several appendices identify WBS elements with (1…n) or similar to denote that one or more of that type of item may be used. Where this structure occurs, the parent WBS (e.g., 1…n) shall be decomposed to the next level and then each child WBS use the appropriate WBS title for each element as well as the WBS numbering identification. For example, if a missile system has multiple DACS subsystems, each DACS Subsystem (1…n) shall have a WBS name designation (for example, "Solid Rocket Motor"), and the element DACS Subsystem 1 would be at the child level of the parent WBS element (DACS Subsystem 1…n) as would DACS Subsystem 2 (for example, "Liquid Rocket Engine"), and so forth. Each WBS should be detailed down to the element's lower level (as defined in the appendices) whenever possible, and assigned the next available WBS number in sequence according to the parent child relationship as shown below.

1.1.2. DACS Subsystem (1…n)
1.1.2.1. Solid Rocket Motor
1.1.2.2. Liquid Rocket Engine
1.1.2.3. Backup Rocket Motor

C.4 DEFINITIONS

C.4.2.8 Kill Vehicle. The complex of hardware, software, data, services, and facilities required to develop and produce the capability of employing a Kill Vehicle in an operational environment to detect and defeat ballistic missile threats. Specific examples include, but are not limited to: THAAD, GBI, and SM-3. A Kill Vehicle is a guided weapon self-propelled after leaving a boosting vehicle that has as its purpose the destruction of a ballistic missile threat and/or a threat re-entry vehicle. It also includes the design, development, and production of complete units (i.e., the prototype or operationally configured units, which satisfy the requirements of their applicable specification(s), regardless of end use).

C.4.2.8.1 Kill Vehicle Structure and Harnesses. The harness is the collection of items used to route and provide electrical power and signals throughout the Kill Vehicle. This is also commonly referred to as "wiring". It provides various passive RF signal flow and conditioning functionality within the Guidance and Control Processing, Navigation, and Communications subsystems. It includes such items as coaxial, fiber optic cables, and installation hardware.

The structure is a collection of items that provide structural support for the components and assemblies of the Kill Vehicle. It includes items such as trusses, frames and shells for carrying primary loads; and secondary structures for equipment support.

C.4.2.8.2 Divert and Attitude Control System (DACS). The complex of hardware, software, and data required to develop and produce the capability to maneuver a Kill Vehicle. The following sub-elements provide the force to alter the attitude and velocity to fix or steer the Kill Vehicle towards the ballistic missile threat.

C.4.2.8.2.1 DACS Integration, Assembly, Test, and Checkout. This element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, interconnect harnessing and software required for the integration, assembly, test, and checkout of the Level 5 elements below into their Level 4 element, DACS.

C.4.2.8.2.2 Divert Subsystem. This subsystem provides thrust for divert control and trajectory corrections as required to accomplish the specified mission. It may also provide thrust for trajectory injection and changes.

Includes, for example:

a. Tanks: propellant or pressurant
b. Plumbing: lines (tubing), fittings, regulators, filters, valves (squib, latch, fill/drain and check), manifolds, transducers, and installation hardware
c. Thrusters: thrusters of different LBFs (Pounds force), monopropellant, and bipropellant
d. Solid rocket motors: nozzle, casing, solid fuel propellant (grain), and ignite
e. Liquid propellant and pressurant: bipropellant fuel and oxidizer, monopropellant fuel, inert gas pressurant, and other gasses/fuel used in the Divert Subsystem

f. Power electronics: power supplies and relay units. Excludes the power generation and distribution associated with the Power and Distribution system.

C.4.2.8.2.3 Attitude Control System. This element determines and controls Kill Vehicle trajectory positions, attitudes, velocities and angular rates using onboard sensors and torque application devices. It may also send control signals to DACS subsystem components, the Power and Distribution system, and communication electronics.

C.4.2.8.2.4 Gas Generator/Structure. Hardware and ordnance to cause the DACS system to begin. Includes bladder pressure and DACS purposes.

Includes, for example:
a. Valves
b. Inert gases
c. Accumulators

C.4.2.8.2.5 Controller Electronics. These elements provide electrical interfaces between the Kill Vehicle processor and sensors and effectors (valves and thrusters, etc.). This WBS element also includes computers or processors that are dedicated to DACS subsystem functions. For effectors, the control Electronics receive the input command from the Kill Vehicle processor and convert it to the corresponding electrical interface stimulus, e.g., pulses, digital to analog converter, etc. for the effector. For sensors, the control Electronics condition the telemetry signal (such as tach pulses, active analogs, etc.) to either an analog signal within the Analog-to-Digital Converter (ADC) range and/or convert to a corresponding digital output.

C.4.2.8.2.6 Ordnance Initiation Set. Upon receipt of an electrical signal from the Kill Vehicle guidance and processing control system, the ordnance initiation set firing units convert the signal into ordnance outputs to the following ordnance events: motor ignition, gas generator ignition, squib ignition, shroud separation, etc.

Includes, for example:
a. Through bulkhead initiators, ordnance test harnesses, squibs, and firing units/exploding bridgewires
b. Power control, switching and distribution units; junction boxes

C.4.2.8.2.7 Flight Termination System. Hardware and ordnance to cause the Kill Vehicle system to cease operation and, if applicable, cause the Kill Vehicle and DACS system to break up. It may include the ability to arm and disarm.

NOTE 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic Systems.

NOTE 2: All effort directly associated with the remaining Level 5 WBS elements and the integration, assembly, test, and checkout of these elements into the Kill Vehicle is excluded.

C.4.2.8.2.8 DACS Software Release 1…n. All DACS subsystem software not associated with a specific Level 4 element above.

C.4.2.8.3 Power and Distribution. This element comprises prime Power and Distribution for the Kill Vehicle.

C.4.2.8.3.1 Power and Distribution Integration, Assembly, Test, and Checkout. This element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, interconnect harnessing and software required for the integration, assembly, test, and checkout of the Level 5 elements below into their Level 4 element, Power and Distribution.

C.4.2.8.3.2 Primary Power. This element comprises Primary Power for the Kill Vehicle.

Excludes, for example:
a. Batteries, which may be integral to other Level 4 elements

NOTE 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic Systems.

NOTE 2: All effort directly associated with the remaining Level 5 WBS elements and the integration, assembly, test, and checkout of these elements into the Kill Vehicle is excluded.

C.4.2.8.3.3 Power Conditioning Electronics. This element comprises prime Power Conditioning Electronics. It excludes power conditioning integral to other Level 4 elements.

NOTE 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic Systems.

NOTE 2: All effort directly associated with the remaining Level 5 WBS elements and the integration, assembly, test, and checkout of these elements into the Kill Vehicle is excluded.

C.4.2.8.3.4 Distribution Harness. This element comprises prime power distribution harnesses.

Excludes, for example:
a. Harnessing integral to other Level 4 elements

C.4.2.8.3.5 Power and Distribution Software Release 1…n. All Power and Distribution subsystem software not associated with a specific Level 4 element above.

NOTE: Refer to Appendix B, Electronic Systems for further breakout and definitions for Software.

C.4.2.8.4 Guidance and Control Processing. Guidance and Control Processing is the process of maneuvering the Kill Vehicle to engage the intended ballistic missile threat. This WBS element is the compliment of hardware, software and equipment for ballistic missile threat detection, signal processing, implementation of guidance laws and generation of guidance commands.

Excludes, for example:
a. Navigation

C.4.2.8.4.1 Guidance and Control Processing Integration, Assembly, Test, and Checkout. This element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, interconnect harnessing and software required for the integration, assembly, test, and checkout of the Level 5 elements below into their Level 4 element, Guidance and Control Processing.

C.4.2.8.4.2 Seeker Assembly. This element comprises the sensors, seeker electronics, Gimbal Assembly, on-gimbal electronics and integral structure(s), which constitutes the Seeker Assembly.

NOTE 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic Systems.

NOTE 2: All effort directly associated with the remaining Level 5 WBS elements and the integration, assembly, test, and checkout of these elements into the Kill Vehicle is excluded.

C.4.2.8.4.2.1 Seeker Integration, Assembly, Test, and Checkout. This element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, interconnect harnessing and software required for the integration, assembly, test, and checkout of the Level 6 elements below into their Level 5 element, Seeker.

C.4.2.8.4.2.2 Optical Telescope Assembly. Optical Telescope Assemblies have optical elements that collect and focus optical energy or create optical waveforms for transmission and/or imaging. These elements are principal light-gathering surfaces of a reflective (using mirrors) and refractive (using lenses) telescopes and related instruments. This element includes primary, secondary, tertiary mirror assemblies (assembly may include associated mounts, mount pads, and other frame).

Includes, for example:
a. Optical assembly structure and mechanisms
b. Thermal control provisions

NOTE: For lower level Common Elements, e.g., SEIT/PM and Support Equipment, reference Appendix L, section L.4.

C.4.2.8.4.2.3 Focal Plane Array. Focal Plane Arrays convert electromagnetic (visible, IR, etc.) into electronic pixels representing the image projected on a plane. Focal planes have image-sensing detectors arranged in arrays (typically rectangular) on sensor chip assemblies (SCAs). One or more SCAs comprise the total focal plane complement of detectors. A focal plane assembly includes SCAs, support structure, optical filters, and wiring.

C.4.2.8.4.2.4 Cooling Assembly. This collection of items facilitates the control of operating temperatures by obtaining or operating at cryogenic (below 150 degrees centigrade) temperatures.

Includes, for example:
a. Bottles
b. Integrated dewar cooler assembly

C.4.2.8.4.2.5 Electronics. These elements perform front-end signal conditioning/processing, signal analog-to-digital conversion, digital-to-analog conversion, focal plane excitation, command execution, telemetry feed-back, and other related electrical power, analog and digital functions. This element only includes electronics that are segregable from the seeker.

C.4.2.8.4.2.6 Gimbal Assembly. This element includes any Gimbal mechanism required for vector movement.

C.4.2.8.4.2.7 Seeker Software Release 1…n. All seeker subsystem software not associated with a specific Level 5 element above.

C.4.2.8.4.3 Guidance Computer. Provides central processing functions, provide timing signals; perform on-board attitude determination, and DACS equipment control (if these are not performed by dedicated DACS computers/Electronics components); and perform thruster control, positioner control, Power and Distribution system monitoring/and control (if this is not performed by dedicated Power and Distribution system components). These elements process data according to a list of computer software instructions (see Guidance and Control Processing

Software). This includes, for example, Central Processing Units (CPUs) or Onboard Computers (OBCs). Computer and Processor memory may also be included within this WBS element.

Includes, for example:
a. Computers and processors that perform general Kill Vehicle computing functions and control, such as command execution.

Excludes, for example:
a. Computers and processors dedicated to DACS attitude determination and control functions, or to payload functions, to the extent that those are separable from the Communication computers and processors performing general functions.

C.4.2.8.4.4 Guidance and Control Processing Software Release 1…n. All Guidance and Control Processing subsystem software not associated with a specific Level 4 element above.

NOTE: Refer to Appendix B, Electronic Systems for further breakout and definitions for Software.

C.4.2.8.5 Navigation. The compliment of hardware, software and equipment to measure or determine body angles and/or body linear motion and generation of navigation commands.

Excludes, for example:
a. Guidance
b. Control

C.4.2.8.5.1 Navigation Integration, Assembly, Test, and Checkout. This element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, interconnect harnessing and software required for the integration, assembly, test, and checkout of the Level 5 elements below into their Level 4 element, Navigation.

C.4.2.8.5.2 Sensor Assemblies. Hardware that provides data for determination of Kill Vehicle location and orientation.

Includes, for example:
a. Global Positioning System (GPS) receiver and antenna
b. Inertial sensors; for example Inertial Measurement Unit (IMU)
c. Star tracker

NOTE 1: If lower level information can be collected, use the structure and definitions in Appendix B, Electronic Systems.

NOTE 2: All effort directly associated with the remaining Level 5 WBS elements and the integration, assembly, test, and checkout of these elements into the Kill Vehicle is excluded.

C.4.2.8.5.3 Navigation Software Release 1…n. All Navigation subsystem software not associated with a specific Level 4 element above.

NOTE: Refer to Appendix B, Electronic Systems for further breakout and definitions for Software.

C.4.2.8.6 Communications. The data link equipment to enable communications between the Kill Vehicle and an external entity (or entities). Data links can be either receive only or send only (one-way) or bidirectional (two way).

Includes, for example:

a. Data transmission and reception for networking, command and control, battle space awareness, and formation management enabling the Kill Vehicle to be a node in a net

C.4.2.8.6.1 Communications Integration, Assembly, Test, and Checkout. This element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, interconnect harnessing and software required for the integration, assembly, test, and checkout of the Level 5 elements below into their Level 4 element, Communication.

C.4.2.8.6.2 Communication Subsystem. This element performs functions such as: formatting and transmitting telemetry; accepting, decoding, verifying, and storing uplink commands; and generating command and control signals based on uplink commands and/or internally generated data.

Includes, for example:

a. Passive radio frequency (RF) components (such as antennas, passive signal flow control), other RF equipment (such as transmitters, receivers, transceivers, transponder, modulators, demodulators, modems, power amplifiers, solid state power amplifiers, downconverters, and upconverters), processors (such as onboard computers [obcs]), solid state memory, decoders, command units, telemetry units, command sequencers, timing units, frequency generators, signal conditioners, data switches, and other electronics

NOTE: For lower level Common Elements, e.g., SEIT/PM and Support Equipment, reference Appendix L, section L.4.

C.4.2.8.6.3 Antenna Assembly. This element is primarily used for Communications specific functions. They receive RF signals for the command and control of the Kill Vehicle and transmit Kill Vehicle telemetry to the ground. These elements are typically omni-directional antennas including support structure and mechanism, but can also be feeds, reflectors, and arrays. Includes the antenna for the GPS receiver.

C.4.2.8.6.4 Communications Software Release 1…n. All communications subsystem software not associated with a specific Level 4 element above.

NOTE: Refer to Appendix B, Electronic Systems for further breakout and definitions for Software.

C.4.2.8.7 Reserved.

C.4.2.8.8 Kill Vehicle Integration, Assembly, Test, and Checkout. This element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, interconnect harnessing and software required for the integration, assembly, test, and checkout of the above Level 4 elements below into their Level 3 element, Kill Vehicle.

C.4.2.8.9 Common WBS Elements. Definitions for Common WBS elements applicable to the Kill Vehicle and all other defense materiel items are in Appendix L: Common Elements, Work Breakdown Structure and Definitions.