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PAL Control of Theater Nuclear Weapons (U)

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PAL Control of Theater Nuclear Weapons (U)

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Abstract (U)

The requirements and objectives of the theater PAL systems are discussed. Current PAL systems, including both hardware and code management, in the European and Pacific Commands are reviewed, and some potential improvements are identified. Advanced development PAL technology also is reviewed. Issues which deserve additional study are presented.

Prepared for Director of Defense Communications Agency, Washington DC, 20305

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Contents (U)

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Tables (U)

Acronyms (U)

AADCOM	Army Air Defense Command
AAFCE	Allied Air Forces Central Europe
ABNCP	Airborne Command Post
ACE	Allied Command Europe
AD	Air Defense
ADM	Atomic Demolition Munition
AEC	Atomic Energy Commission
AFAP	Artillery Fired Atomic Projectile
AFCENT	Allied Forces Central Region
AFNORTH	Allied Forces Northern Region
AFSOUTH	Allied Forces Southern Region
AK	Adaption Kit
ALCM	Air Launched Cruise Missile
AMAC	Aircraft Monitor and Control
APC	Automated PAL Controller
APS	Active Protection System
ASW	Antisubmarine Warfare
ATAF	Allied Tactical Air Force
BALTAP	Baltic Approaches
C3	Command, Control, and Communication
C3S	Command, Control, and Communication System
CAP	Code Activated Processor
CES	Code Enable Switch
CD	Command Disable
CDS	Command Disable System
CENTAG	Central Army Group
CINCLANT	Commander in Chief Atlantic
CINCPAC	Commander in Chief Pacific
CLS	Classified Logistics Shipping
COMUSK	Commander US Forces Korea
COMUSMFK	Commander US Marine Forces Korea
CSM	Cipher System Module
DCA	Defense Communications Agency

Acronyms (cont) (U)

DIVARTY	Division Artillery
DOD	Department of Defense
EA	Emergency Action
EAM	Emergency Action Message
ERDA	Energy Research and Development Administration
ESD	Environmental Sensing Device
EUCOM	European Command
FA	Field Artillery
FFSS	Forward Field Storage Site
FSS	Field Storage Site
GEP	Group Employment Plan
GLCM	Ground Launched Cruise Missile
GSU	GLCM Security Unit
HCP	Headquarters Code Processor
ICU	Integrated Control Unit
IOC	Initial Operational Capability
IPS	Integral Protection System
JCAE	Joint Committee on Atomic Energy
JCS	Joint Chiefs of Staff
LCC	Launch Control Center
MAF	Marine Amphibious Force
MC	Military Characteristics
MCCS	Multiple Code Coded Switch
MCCSS	Multiple Code Coded Security Switch
MCP	Missile Command Post
MOB	Main Operating Base
MUNSS	Munitions Support Squadron
MWWU	Marine Wing Weapons Unit
NASP	Nuclear Ammunition Supply Point
NCA	National Command Authority
NH	Nike Hercules
NMCC	National Military Command Center
NON	North Norway
NOP	Nuclear Ordnance Platoon
NORTHAG	Northern Army Group

Acronyms (cont) (U)

NSA	National Security Agency
NSAM	National Security Action Memorandum
NST	Nuclear Support Team
OB	Ordnance Brigade
PACOM	Pacific Command
PAL	Permissive Action Link
PDM	Portable Data Module
PIA	Pershing IA
PMCT	PAL Management Control Team
QRA	Quick Re[illegible]ion Alert
ROC	Required Operational Capability
ROK	Republic of Korea
SACEUR	Supreme Allied Commander Europe
SACLANT	Supreme Allied Commander Atlantic
SAS	Sealed Authenticator System
SASP	Special Ammunition Supply Point
SCS	Security Container System
SDM	Source Data Module
SEP	Selective Employment Plan
SETAF	Southern European Task Force
SHAPE	Supreme Headquarters Allied Powers Europe
SHOC	SHAPE Operations Center
SIOP	Single Integrated Operational Plan
SIP	System Improvement Plan
SLCM	Sea Launched Cruise Missile
SLO	Stabilization Lockout
SNL	Sandia National Laboratories
SONOR	South Norway
SSBN	Submarine Strategic Ballistic Nuclear
SSP	Scheduled Strike Program
TFW	Tactical Fighter Wing
TNF	Theater Nuclear Force
TNW	Theater Nuclear Weapon
UDL	Use Denial Lock

Acronyms (cont) (U)

USAAG	US Army Artillery Group
USAFAD	US Army Field Artillery Detachment
USAFE	US Air Force Europe
USAFK	US Air Force Korea
USAREUR	US Army Europe
USCINCEUR	US Commander in Chief Europe
USCINCLANT	US Commander in Chief Atlantic
USG	Unique Signal Generator
USNAVEUR	US Navy Europe
WSD—K	Weapons Support Detachment—Korea

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PAL Control of Theater Nuclear Weapons

1. Introduction (U)

(U) The Defense Communications Agency (DCA), Planning and Systems Integration Division, has been requested by the Office of the Secretary of Defense (OSD) to undertake the task of planning improvements to the Command, Control, and Communications (C3) System which supports theater nuclear forces (TNFs) in the US European Command (EUCOM) and Pacific Command (PACOM). System Improvement Plans[1 2] (SIPs) for both theaters, based on Required Operational Capability (ROC) generated by theater personnel, have been drafted by DCA. These documents reflect the need, expressed in ROCs from both commands, to improve the present Permissive Action Link (PAL) code management system. The DCA has asked Sandia National Laboratories (SNL) to perform a preliminary review of the PAL systems in PACOM and EUCOM and generate a reference document for ROC validation and SIP review. It is also intended that this review attempt to identify and describe potential improvements to existing capabilities beyond those discussed in the existing ROCs.

(U) Section 1 of this report seeks to compile, through historical review, the requirements and objectives of the theater PAL systems as they exist today. Section 2 reviews and discusses the PAL systems in PACOM and EUCOM as they existed in the 1982-83 time frame. Both hardware elements and code management are discussed. In Section 3, areas of possible improvement are presented. Section 4 reviews advanced development currently under way, and Section 5 discusses system improvement and issues which deserve more detailed study than is possible in the context of this report.

1.1 PAL and Nuclear Weapons Command and Control (U)

(U) The President of the United States and the Secretary of Defense (or their designated successors) comprise the National Command Authority (NCA) in which is vested the sole authority to order the use of US nuclear forces. Nuclear weapons C3 systems are designed to provide assurance that the risk of unauthorized use of US nuclear weapons is acceptably small. At the same time, C3 systems must provide the capability for the President to exercise his authority should he deem it necessary. The dual nature of the C3S objective was aptly summarized by a joint ERDA/Army working group which described the objective as follows: "to provide effective control while retaining maximum operational flexibility and minimum restrictions on National Command Authority actions and alternatives."[3]

(S)Control of nuclear weapons has historically included two complementary elements: administrative measures and mechanistic systems. Administrative measures (e.g., guards, exclusion areas, no-lone zones, and sealed authenticator systems) are designed to limit access to the weapons themselves or to critical information.[4 5] The effectiveness of such measures depends on the reliability and dedication of the involved Department of Defense (DOD) personnel. Mechanistic systems have been based on disenabled weapon hardware. [redacted] The effectiveness of such systems depends on the difficulty in circumventing the disenabling hardware and is measured by the length of delay afforded by the protective mechanism. DOE b(3)

(U) During the past 20 years several mechanistic systems have been developed, including the positive enable system for Minuteman, the bomber coded switch, the Titan coded switch, and the PAL system for theater nuclear weapons. The historical evolution of the PAL system is described in the next section.

1.2 History of PAL

(U) In the years immediately following World War II, the issues of nuclear weapon safety, security, and control were thought to be adequately addressed since the weapons were either deployed within the US or with sizable US units abroad and since the inherent design of the early weapons physically separated critical nuclear components from the rest of the weapon system. This precluded nuclear detonation prior to final weapon assembly. These components were maintained in the custody of the Atomic Energy Commission (AEC) (part of which is now the Department of

Energy (DOE)) until the President authorized transfer to military units for assembly and delivery. Increasing concerns with readiness/reaction times led first to the development of weapons with inflight insertion of the nuclear components and ultimately to sealed pit ("wooden bomb") designs. These weapons are complete rounds which require very little preparation for use.

(U) In February 1957, the Armed Forces Special Weapons Project (now the Defense Nuclear Agency) initiated a series of safety studies of the stockpiled sealed pit weapons. These studies led to the concept of a trajectory or environmental sensing device (ESD) which would interrupt critical warhead electrical systems until a characteristic delivery environment (spin acceleration, velocity, etc) was sensed. The W49 warhead (carried by the Thor, Atlas, and Jupiter missiles) was the first stockpiled weapon to receive ESDs. The W49 retrofit program was complete by the summer of 1959, and a family of ESDs was under development for incorporation in other weapons.

(U) ESDs cannot be devised for Atomic Demolition Munitions (ADM) whose delivery environments are not easily distinguishable from other elements of their stockpile-to-target (STS) sequences. In lieu of ESDs, ADMs were fitted with 3-digit combination locks (50^3 or 1.25×10^5 code population). The locks prevented physical access to critical arming components. Unlocking these devices provided an extra step in the prearming sequence which increased handling safety. In August 1959, in response to the DoD desire for a remote unlocking capability, Sandia began to develop the concept of a remotely-operated combination lock. By June 1960, a number of possible mechanical design approaches had been identified.

(U) In parallel with the increase in concern for nuclear safety, the issues of nuclear weapon security and control began to assume a higher profile in the late 1950s. In June 1957, the NATO Military Committee called for the use of non-US NATO delivery systems to be used in addition to US systems in case of a massive nuclear response. In December 1957, the NATO Military Commitee formally requested President Eisenhower to establish a NATO nuclear stockpile under US custodial control. Within a month, the President had requested an amendment to the Atomic Energy Act of 1954 to allow the transfer of limited restricted data and nonnuclear weapons system components to some NATO allies.

(U) In June 1958, Congress passed PL 85-479 which accomplished these goals and paved the way for the negotiation of bilateral programs of cooperation between the US and various NATO allies. Each of these agreements provides for the deployment of US weapons to the host country for use by NATO forces. The weapons remain under US custodial control until transfer is authorized by the President. The host country assumes primary responsibility for the security of the weapons. The deployment of weapons to support non-US NATO forces significantly increased the number of US weapons abroad. Since most of these weapons were not sealed pit types, custodial control of the critical nuclear components was deemed adequate.

(U) In 1960, the Supreme Allied Commander in Europe (SACEUR) decided to place some of his nuclear forces on Quick Reaction Alert (QRA). This required assembled warheads to be mated to NATO aircraft and missiles. The first QRA units became operational in July 1960. By late 1960, concern had arisen in several quarters over possible unauthorized use of NATO weapons.

(U) During the summer, Sandia had begun to discuss the use of remotely operated combination locks as command and control aids with the AEC Department of Military Application; by November, prototype coded switch hardware (a 10^4 code population electromechanical device) had been demonstrated. In October, the AEC had requested Los Alamos Scientific Laboratory and Lawrence Livermore Laboratory to study concepts for devices to enhance the safety and use control of NATO weapons. During November and December, members of the Joint Congressional Committee on Atomic Energy (JCAE) toured weapon storage sites in Europe to assess the adequacy of US custodial control. Their report, which was delivered to newly-elected President Kennedy in February 1961, suggested that with respect to custodial arrangements for US weapons in an alert posture, the DoD was not in compliance of Section 92 of the Atomic Energy Act which specified US possession of all US weapons.

(U) By April 1961, three DoD committees had been formed to study the use control issue: the Special Warhead Arming Control (SWAC) Committee under the Defense Atomic Support Agency (now DNA), the Safety Steering Group under Dr. Marvin Stern (the Stern Committee) in the Office of Deputy Secretary of Defense for Research and Engineering, and Project 106 (j), the Joint Command and Control Study Group under the Joint Chiefs of Staff (JCS). By August, all of these groups had focused on the concept of a permissive link to preclude weapon arming without the use of a controlled numerical code. At about the same time, the Director of Military Applications DOE had requested a Sandia study on the availability of code-controlled special warhead arming devices.

(U) As a result of these studies, in August the Secretary of Defense formally requested the AEC to develop permissive links for NATO weapons. In September, the Director of Military Applications requested Sandia to continue developing the Permissive Action Link (PAL), as they had come to be called, and to report a plan for retrofitting NATO weapons with these devices. This report was delivered in January 1962.

(U) In March, the JCAE convened to discuss the adequacy of existing weapon custodial arrangements. They reported an urgent requirement to develop the permissive link technology. In May, the President convened a study group under Science Advisor Jerome Wiesner to report a plan for incorporating permissive links in NATO weapons. After receiving Weisner's report, the President issued National Security Action Memorandum (NSAM) 160[6] on June 6, 1962. This Order directed that all US weapons deployed to NATO be equipped with permissive links. In February 1972, following a visit by members of the JCAE to the Pacific theater, the Secretary of Defense decided to extend PAL control to weapons deployed on foriegn soil in the Western Pacific area.

(U) NSAM 160 also directed the establishment of a research program aimed at developing more advanced PAL devices and thus initiated a program of research, development, and implementation of PAL hardware that continues today. In response to NSAM-160, the DoD integrated new command and control hardware with all existing NATO-based systems. The short-range theater systems were fitted with 5-digit mechanical combination locks. The W31 Nike Hercules and Honest John missiles, the W45 and W54 ADMs, the W54 Davy Crockett projectile, and the W33 and W48 artillery-fired atomic projectiles (AFAPs) were equipped with these locks.

(U) Meanwhile, a crash program was initiated to finish development of the electromechanical, 4-digit (10^4 code population) coded switch (MC1541) and its associated control equipment. This device, known as Category A (CAT A) PAL, was retrofitted to the existing long-range systems. These included the W49 Jupiter IRBM, the B7 and B28 gravity bombs, and the W28 Mace, W50 Pershing, and W52 Sergeant tactical missiles.

(U) In mid-1961, development of Category B (CAT B) PAL had already begun.[7] This device (MC1707) was also an electromechanical, 4-digit coded switch, but it could be controlled by fewer wires than were required for CAT A PAL. This made it practical to unlock PAL from an aircraft cockpit. CAT B PAL incorporated a number of other improvements, including the ability to recode and check the operational code without unlocking the PAL, decreased operation time, and a code-controlled lock operation. The B28, B43, and B57 gravity bombs were modified to accept CAT B PAL. CAT B was included in the baseline B61 design and fielded in the B61-0.

(S) By 1964, command and control hardware in the form of mechanical locks and CAT A and B PAL devices (and their associated control equipment) were available to provide code control for all weapons deployed to NATO.

DOE b(3)

(U) Development of the improved CAT B PAL began in 1965.[8] The objective of this effort was to provide a "limited try" feature that would preclude an exhaustive-search attack, in which all possible codes are tried until the switch unlocks. This improved switch (MC1707A), called CAT B′ PAL, was fielded in only one weapon system, the W72 Walleye guided glide bomb.

(U) In 1971, the Military Characteristics (MC) for the W70 Lance warhead were amended to require a 6-digit, limited-try PAL for the initial WR production.[10] This requirement was met by extending the design of the CAT B′ PAL to accommodate a 10^6 code population. The resulting component (MC2607) was called the CAT C PAL; it was fielded only in the W70-0.

(C) The first electronic PAL device, the MC2764 Multiple Code Coded Switch (MCCS), began development in late 1970.[11]

DoE b(3)

(U) The foregoing historical sketch has emphasized the technical evolution of PAL equipment. Development of objectives and requirements for PAL is discussed in more detail in Section 1.3.

1.3 PAL Objectives and Requirements (U)

(U) For 20 years, the maintenance of a PAL system for theater nuclear forces has been a policy of the US Government. A clear understanding of the objectives behind the policy is necessary to evaluate the effectiveness of the existing PAL system and to identify potential improvements to that system. The following sections review historical and current documentation related to the PAL policy in an effort to establish the objectives against which today's PAL system can be measured.

DoE b(3)

1.3.1 Objectives and Requirements—Historical Perspective (U)

(U) The extraordinary care taken with nuclear weapons by the DOD reflects the underlying concern, as stated in Air Force Regulation 122-10[16], of the US Government that:

> "Because of their political and military importance, their destructive power, their cost, and the consequences of an unauthorized or accidental nuclear or high explosive detonation, nuclear weapons must be protected against the risks and threats inherent in their environment.
>
> a. The conservation of nuclear weapons as a national resource and the safety of the public, operating personnel, and property are of paramount importance. These weapons and weapon systems must be designed to incorporate maximum safety consistent with operational requirements.
>
> b. Nuclear safety requirements are to prevent nuclear accidents and to minimize both the number and consequence of nuclear incidents and deficiencies."

(U) The concern is codified in Section 92 of the Atomic Energy Act of 1954 (or the Atomic Energy Act of 1946, as amended) which states:

> (U) "It shall be unlawful for any person to transfer, rece e in interstate commerce, manufacture, produce, transfer, acquire, possess, import or export any atomic weapons, except as may be authorized by the Commission pursuant to the provisions of Section 91."[17]

(U) In 1960, Congress, as discussed above, became concerned that US arrangements for employment of US nuclear weapons by NATO forces (in particular those policies and procedures governing weapons placed in an alert posture with non-US NATO delivery units) were not in compliance with this law, since possession of a U.S. atomic weapon by any person (including agents of a foreign government) is prohibited. A series of subsequent studies developed the concept of a PAL device that would preclude arming a weapon without receipt of a coded signal. Thus, possession of information necessary to arm a weapon was added to the sometimes minimal custodial presence.

(U) In March 1962, the JCAE met to examine the legality of existing arrangements for possession and control of US nuclear weapons in NATO. The committee recommended ". . .that an urgent requirement should be established to develop such controls and devices," i.e., the PALs.

1.3.1.1 NSAM-160 (U)

(U) In June 1962, President Kennedy issued National Security Action Memorandum No. 160 (NSAM-160) which ordered the installation of PALs on all US nuclear weapons in NATO. An attached memorandum by Presidential Science Advisor Jerome Wiesner describes the capabilities of existing PAL devices and presents deployment options. NSAM 160 ...e attached memo are included in Appendix A. ... memo listed four possible objectives for PAL. In order of increasing technical difficulty, these were:

OSD b(3)

(C) Except for number 2, these objectives are stated in terms of the adversary against which PAL might provide protection.

(U) It was not Wiesner's intent to suggest a particular objective for PAL: DoE b(3)

> (C) "For the purpose of this review, I have not attempted to meet a specific objective but rather have analyzed the operational value of the best available equipment."

(U) Rather, he wanted to present options for the implementation of PAL, but

> (C) ". . .the decision as to the extent to which permissive link equipment should, in fact, be

incorporated in dispersed weapons can be made solely in terms of broad policy considerations as to the desired objective."

[redacted]

DOE b(3)

1.3.1.2 PAL General Characteristics (U)

(U) In September 1962, the Secretary of Defense approved a set of DoD design guidelines for PAL systems. These guidelines, entitled "General Characteristics for Permissive Devices for Use With Nuclear Weapons," or revisions thereof have served since that time as standards in specifying PAL devices in the MC of new weapons systems. The original guidelines and the four revisions (1969, 1970, 1972, and 1980) are included in Appendix B.

(U) The statement of purpose in the first edition of the General Characteristics of PAL defines:

> (U) "an arming control device for use with designated nuclear weapons which is intended to provide some additional physical means for preventing unauthorized use of nuclear weapons."[18]

(U) A number of specific design requirements are included. Most of these relate to specific operational features of the PAL system or to issues of compatibility with the rest of the weapons system. For instance, the PAL system

- (U) must not degrade weapon safety or reliability
- (U) must be compatible with weapon operational concepts as stated in the STS
- (U) must not significantly lengthen the reaction time for the weapon system

(U) These requirements are restated in all subsequent versions of the General Characteristics. However, as suggested in the Weisner memo, the objective of this system and its reason for existence is based on its ability to protect the weapon against unauthorized use by a potential adversary. Of the twelve specific design requirements stated in the original document, only one relates to the performance of PAL against an adversary.

[redacted]

DOE b(3)

(U) Thus, the objective in terms of an adversary is not specified. However, some bounds are placed on the adversary's capabilities. The *function* of PAL is stated in terms of delay following unauthorized access to a weapon.

(U) In the 1969 edition, the stated purpose is

> (U) "To provide general characteristics for permissive action links incorporated in weapons systems to prevent unauthorized nuclear detonation."[19]

[redacted]

DOE b(3)

(U) In 1972, a new edition was prepared to include all existing PAL technology. While the statement of purpose remained essentially the same as in the 1969 edition, PALs are defined as

> (U) "devices and subsystems designed to reduce the possibility of obtaining a nuclear detonation from a nuclear warhead without the use (insertion) of a controlled numerical code, thus reducing the probability of an unauthorized nuclear detonation."[20]

[redacted]

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(U) The 1962-1980 evolution of PAL characteristics is marked by several features.

- (U) Compatibility with other weapon systems requirements, such as safety, reliability, reaction time, and deliverability, is specified.
- (U) All versions emphasized the prevention of unauthorized nuclear detonations as the general objective of PAL.
- (U) All versions recognized the function of PAL as delay of unauthorized detonation once unauthorized access to weapons has been achieved.
- (U) Numerical standards of performance were stated in terms of minimum delay times associated with different types of PAL systems. However, these standards were not explicitly related to the function of the overall command and control system.

DOE b(3)

(U) In April 1980, the current version of the General Characteristics of PAL was published. This document is discussed below.

1.3.2 Current Objectives and Requirements (U)

(U) In this section, current documentation relevant to PAL policy is reviewed to determine the objective against which the performance of today's PAL system may be measured.

1.3.2.1 The Executive Requirement (U)

(S) The executive requirement for PAL originated with NSAM-160, which was rescinded in December 1976.

1.3.2.3 Military Requirements (U)

(U) The executive requirement for PAL is promulgated through the Joint Chiefs of Staff (JCS).

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DOE b(3)

(U) Today, the commanders of the unified and specified commands to which nuclear weapons are allocated are responsible to the President and the Secretary of Defense to:

> (U) "establish and supervise the policies, practices and responsibilities for the storage, safety, security, custodial control, deployment, and utilization of nuclear weapons."[23]

DOE b(3)

(U) Explicit reference to PAL in relation to the theater commander's custodial mission and in particular to his weapon security responsibilities does not appear in either Ref 23 or 24.

DOE b(3)

1.3.2.4 Related Documents (U)

(C) A letter from James P. Wade, Jr., Chairman of the Military Liaison Committee, to Duane Sewell, Assistant Secretary for Defense Programs, dated 18 April 1980, accompanied the current version of the PAL General Characteristics. This letter (Appendix C) comments on the role and function of PAL. The function of PAL as delay is emphasized. However, a broader role is presented for PAL than that envisioned in today's theater implementation.

DOE b(3)

(U) A third relevant document[28] from the office of the Assistant to the Secretary of Defense for Atomic Energy summarizes measures currently being implemented to upgrade the safety and security of nuclear weapons. Among the issues discussed in this document are

- Improvements in physical security to minimize the likelihood of loss of control of a nuclear weapon
- Stockpile improvement programs that address, among other things, modernization of the PAL protection in some of the older systems expected to remain in stockpile
- Modernization of DoD policy directives to clarify standards and criteria for positive control measures for nuclear weapon systems.

1.3.3 Summary of Objectives and Requirements (U)

(U) A review of historical and current documents and examination of today's theater PAL systems lead to the following conclusions:

- (S) The requirement for PAL originated at the Presidential level and is promulgated through the JCS. This requirement states that all TNWs deployed to foreign soil will be PAL-equipped. Responsibility for implementing and operating the PAL code-management system is delegated to the theater CINC. DOE b(3)
- (U) PAL must be compatible with all other weapon system requirements.
- (C) The function of PAL devices was historically recognized as delaying for a period of time, after unauthorized access to a weapon has been gained, the unauthorized detonation of that weapon. This is also the recognized function of PAL today.
- (C) The operational context in which today's theater PAL systems function suggests that PAL is one measure which protects against unauthorized use by US or Allied forces. Additionally, some benefit (delay) would be provided if outsiders (terrorists or host nation forces) were to gain access to a weapon. However, no explicit and agreed-upon definition of the threat against which PAL is intended to provide protection currently exists. Such definition would be useful in assessing the performance of todays PAL system.

2. PAL Systems Today (U)

DOE b(3)