[redacted]

SC.DC-67-2117

SCIENTIFIC CONSULTANTS

THE DIKEWOOD CORPORATION

4805 MENAUL BOULEVARD N.E.
ALBUQUERQUE, NEW MEXICO

July 8, 1963

UNCLASSIFIED

Sandia Corporation
Attn: D. R. Cotter, 9100
P.O. Box 5800
Albuquerque, New Mexico

Subj: Transmittal of Letter Report on P.O. 37-0086, suborder 2

Gentlemen:

Enclosed are three copies of LR-1032-2-2, the last of a series reporting work on suborder 2 of P.O. 37-0086.

Sincerely yours,

C. R. Carlson
Project Supervisor

CRC:es

Encl:

cc: D.R. Cotter, w/encl. ~~cys. 1, 2, 3/4A; 5-1032-2-2~~
John Hart, Purch. Org. w/o encl
File, w/encl. cy. ~~4/4A~~

SANDIA SYSTEMATIC DECLASSIFICATION REVIEW DOWNGRADING OR DECLASSIFICATION STAMP	
CLASSIFICATION CHANGED TO: U	AUTHORITY: K. D. Smith
Emilda Selph 05-23-96	
PERSON CHANGING MARKING & DATE: R. I. Ruff 6/19/96	RECORD ID: 96SN024
PERSON VERIFYING MARKING & DATE	DATED: 01-16-96

TRANSMITTAL

Encl.

[redacted]

[redacted]

UNCLASSIFIED

[redacted] SC-DC-67-2117

THE DIKEWOOD CORPORATION
4805 MENAUL BOULEVARD, N.E.
ALBUQUERQUE, NEW MEXICO

UNCLASSIFIED

INVENTORIED

AUG 15 '66

July 7, 1963
L.R. 1032-2-2

D. R. Cotter, 9100

3428-2

Subject: Letter Report on Suborder 2 of P.O. 57-0086

Refs: 1. SCTM 277-62(91), Advanced Prescribed Action Link (PAL) Devices, A. V. Engel, Jr., Nov. 1962, SRD
2. LR-1032-2-1, Military Exercise of Weapon Systems with PAL Devices, 25 Mar. 1963, Conf.

INVENTORIED

DEC 14 1964

3427-1

Introduction

Nuclear weapons were adopted, first of all, as tools of warfare unprecedented in destructiveness per unit mass. Their, for a time, one-sided availability made them without doubt the decisive element in the world balance of military power. Nuclear capability, just by existing, was effective. There was no need for proliferation in yields and types for wide deployment, for immediate readiness, or for the training of more than a highly restricted, elite cadre of special weapons personnel. As a result there was no pressing necessity for accepting any risks of nuclear accident or incident. In the limit, the weapons themselves did not even have to be constructed prior to the outbreak of unequivocal war.

Two developments have forced changes: first, the growth of opposing nuclear capability, and second, the calculated enemy recourse

UNCLASSIFIED

[redacted]

[redacted]

to "equivocal" hostilities or so-called limited wars. In these actions the introduction of nuclear weapons is not clearly positive in value because their tactical effectiveness is still untried and in question, and the broader consequences of their use can not be predetermined.

The two-sided nuclear capability race has now degenerated to the point where:

1. Having the most weapons is not a significant advantage if, indeed, it is an advantage at all.
2. Major national military doctrines are designed to minimize the advantage of striking first.
3. It would be absurd for either side to assign planning weight to quality-differences in the opposing nuclear weapon systems.

In this situation, which might be termed a "paper stand-off", it is still necessary to postulate and to plan for several levels of active nuclear combat other than full intercontinental exchange. Should any such combat begin, the advantage will clearly rest with the side that learns more rapidly and adapts more readily to the unknown experience of two-sided nuclear tactics. Just to preserve an option on this advantage requires a constant preparedness-proficiency of personnel, flexibility in doctrine and tactics, low inertia in response.

As an inevitable result of doctrinal emphasis on less-than-maximum levels of nuclear exchange, the U.S. option on tactical advantage must be

strengthened. Survival alone of tactical nuclear forces requires increased numbers of weapons and hence of weapon-tending military personnel. Wider deployment becomes increasingly necessary to reduce vulnerability, to demonstrate intent, and to shorten reaction time while broadening the geographical areas of response. With these changes unavoidably come increased risks of accident and incident.

The Tactical Nuclear Problem

In a sense the operational evolution of tactical nuclear weapons systems is today paralleling, probably by default, that of the intercontinental strategic systems. Strategic system concepts have become reasonably firm. Except for the special case of Polaris submarines, the mobile-base system has fallen in emphasis in favor of the rigid, widely deployed, short reaction, fixed-base organization. It seems more than reasonable to assign this outcome to a much heavier weighting of (1) more positive command and control and (2) minimum reaction time than to considerations of vulnerability. The communication net seems impressive (giving the benefit of some doubt to the Polaris system) and the strategic capability can now be alerted and drilled as desired.

The fixed-base systems allow elaborate simulation under quite realistic circumstances. The strategic base personnel, if they survive and are ordered into action, will operate from the same chairs, before the same consoles, and observe the same routines. Administrative reins are today relatively good, can be made tighter, and the risk of accident or incident is

reasonably under control. The only really loose ends remaining in the system are the airborne alerts and exercises which are only "fail-safe" in an administrative sense. This loophole can be closed by a simple PAL system and, in fact, the existence of a PAL-like lock has been advertised for years despite the minor detail of its not having beeen installed.

Just as it became clear that a large stock of strategic bombs buried at Site Able were no capability at all, so it is becoming clear that a tactical capability iglooed and barbwired even in far-flung depots can be virtually useless. It might even be a step upward in tactical capability to remove the weapons to the U.S. and assign the security troops to combat units.

The status quo must be changed. At least semi-officially, the withdrawal of tactical nuclear capability from without the ZI has been proposed for consideration. This would indeed be an extreme measure. While it would certainly be a step in the direction of maximum safety from accident or incident, it serves to emphasize the larger safety problem underlying the original presence of nuclear weapons in overseas theatres. National safety demans that a nuclear capability exist whether it be to give pause to the enemy, to give some comfort to allies, or to give the U.S. a contingency option. Again, it seems obvious that the present situation--almost a mothballed tactical capability--poorly serves any such purposes.

The remaining alternative is further deployment to make weapons available, to exercise troops in their preparation, in maneuver, and in "best guess" tactics. Unless the hardware and handling elaborations over

the last few years in the name of "inherent safety" have been futile, the primary question today should not be whether users and bystanders are safe enough from the weapons themselves, but whether there is adequate protection against subversion, psychopathic malevolence, irresponsibility, and misdirected initiative.

Clearly there is no possibility or desire to transfer presidential authority over nuclear weapon committment to the user troops. Instead a way is sought to transfer positive control over the firing of live weapons, normally in the hands of the troops, to higher authority. This can be done in principle only if it is possible to provide a positive communication link to each firing site, regardless of whether control is to be exercised directly by electrical means or indirectly by the transmission of enabling orders and instructions. Note that if it were possible to construct such a control network the tactical system is, at least for initial operations, converted to a soft fixed-base system in imitation of the strategic capability. Individual weapon units that are connected to the net by the final link may have some limited freedom for flailing about the countryside, but this radius of freedom beyond the last relay is certainly restricted to no more than a very few miles whether it be set by feasible runs of land line or by reliable ranges for mobile radio communication. The system can easily be mapped in advance by enemy intelligence and is at all times highly vulnerable, though perhaps less so than weapons initially concentrated in igloo areas.

As a necessary condition, therefore, the concept of command and control over the act of firing definitely must await substantial improvement in tactical communications. Even so, the technological ability, if it comes, is not a sufficient condition, for the operational background does not exist.

The first compromise involves chopping the weapon units free of the communication net as early as possible in the development of imminent hostilities. This increases their flexibility and their chances for survival. It has unfortunate (perhaps) overtones in that there is certainly implied some reliance on troop-level command initiative in the actual firing of nuclear weapons. This is an unavoidable consequence of inability to provide and insure higher-level command control over the firing of each and every battlefield nuclear weapon. Such an operational concept is an untried and unvalued feature of warfare. It seems rash to deny that one live weapon in the bush is worth one, two, or more tranquilized on the Bull's-eye.

Given that actual firing can not be controlled on an absolute basis, one can hope only to delay the end of the weapon "tranquilization" period as long as possible--this by implementation of the PAL ARM-ENABLE concept. This type of operation is itself a difficult one. Among other things it requires:

(1) Recognition that it is militarily necessary to place troops on red alert.

(2) Timing of arm-enable orders while the communication net is still intact to all units.

(3) Pre-planning and pre-training to take maximum advantage of the fact that some, perhaps many, nuclear-capable units will disperse into the bush under uncertain control.

While (3) may seem fundamentally disturbing it is in actuality no different from the "fail-safe" strategic bomber exercises that have been part of the nuclear scene for several years. A fail-safe firing doctrine can as readily be instituted among tactical forces; it is difficult to prove objectively that such a measure would be less reliable.

The term fail-safe has different meanings, almost opposite, depending upon whether the base situation is peace or war. In peacetime one prefers nuclear duds following any breakdown in the system; in war it is hard to rationalize that a total loss in firepower should follow because a-priori provisions for controlling the nuclear capability prove inadequate or unworkable. The real root of the problem is the distinction between peace and war, and no hardware system will make and enforce <u>that</u> decision.

<u>The Nature of Weapon Control</u>

The balance, nuclear-safety-in-the-cold-war versus military-"safety"-in-a-tactical-war, is now unsatisfactory. Weapons locked up at home base may suitably satisfy the former, but obviously jeopardize the latter. Some means is sought to extend the control offered by central storage of weapons to those weapons dispersed and deployed among field units. In a sense this means of control is a safety device, yet clearly the motivation is not that of maximizing safety, but instead is that of increasing capability for nuclear response. This difference is an important one for implementation of such a control method. Furthermore, it can be shown that such a control

device must inevitably fail to be a safety device when the risks of an accident or incident are highest, i.e., when tension has mounted to the stage of full alert and the control must be removed. To repeat, this failure is a consequence of inability to effect (with reasonable reliability) coincidence of ENABLE and FIRE orders. This inability, in turn, is not solely a result of technological deficiency in the communication state-of-the-art; it is an operational problem involving all aspects of battlefield intelligence, tactics, and maneuver in a type of warfare still unexplored.

The type of control system embodied in the PAL device concept discussed in References 1 and 2 can not then serve as a safety measure in times of greatest need, namely when the threat of war and enemy movements contributing to threat or constituting actual local provocations have raised the tension level among nuclear-capable U.S. defensive forces to a peak. The choices under a PAL system in time of unmistakable war tension are as follows:

(1) Proceed with RED alert orders, transmit ARM ENABLE codes, and allow full freedom for field units to disperse and maneuver according to existing emergency plans and provisions for contingencies. Hope that communication nets will develop for transmission of FIRE orders when and if decided upon.

(2) Proceed as in (1) but withhold ARM ENABLE codes. Hope for communication capability to transmit ARM ENABLE or ARM ENABLE and FIRE orders when and if decided upon.

(3) Proceed with less than full-scramble alert, tying field units to last stage communication relay points as long as possible.

It is simple to order these alternatives in terms of their gross characteristics:

	Vulnerability to Enemy Action and/or Subversion	Preservation of Capability for Subsequent warfare	Risk of Accident and/or Incident
Max	(3)	(1)	(1)
Intermed	(2)	(2)	(2)
Min	(1)	(3)	(3)

The only feature recommending (3), the sit-tight alternative, over present deployment is that it multiplies the number of initial targets that the enemy must consider. This however, can only be regarded as a transient enemy problem that is easily solved given time and expected growth of enemy capability. Choice (2), scramble-with-duds, poses more of a dynamic field-intelligence and counter-maneuver problem for the enemy, but permits him more time to solve it without suffering major nuclear threat. It also forces U.S. concentration on establishing, with utmost priority, a two-way communication net--this certainly insures a maximum of traffic (and confusion) that will greatly assist the enemy intelligence effort. Choice (1) scramble-with-live weapons, can only be modified by administrative inclusion of the "fail-safe" (SAC exercise) concept of "don't fire without receipt of further orders." In spite of such a modification (1) still would

differ from (2) in two major respects: first, the communication requirements are less rigid since FIRE orders need not be accompanied by ARM-ENABLE codes--the traffic pattern and routing from origin to destination can be more flexible; second, operational flexibility is maintained because control is still not absolute--the unit commander can take the initiative if it develops (as must be expected) that the war can not be directed shot by shot from central control.

To summarize, there are two basic conclusions concerning the technological control of tactical nuclear weapons:

1. Removal of control and transmission of fire orders cannot be expected to be coincident events for non-fixed-base nuclear systems.

2. Removal of control is unavoidably accompanied by higher risks of nuclear accidents and incidents.

Only in this light can reasonable requirements be derived for PAL devices. Most importantly, the optimum solution is strongly influenced by the operational nature of real alerts: these operations--with WR weapons--can not be formulated, tested, and evaluated until exercises are possible. Exercises will not be possible until a PAL system is accepted and installed. This initial system, therefore, should place minimum operational constraints on the military. In this sense flexibility is higher in priority than simplicity. As a consequence, the overriding requirements are taken to be:

1. Reliable insurance of inert weapons in the hands of troops during peacetime.

2. Full provision for troop exercises with WR weapons. (cf Ref. 2)

PAL Hardware

Any control device is fundamentally a lock operable by some form of key to reduce the time for unlocking from "long" to "short". For the purposes of a PAL device any control is equivalent to a lock and key. The key in turn is informational in nature because information is easiest to transmit. Transmitted information could, of course, be employed to make possible the remote manufacture of a hardware key--an illustration of this alternative was elaborated upon in an earlier Dikewood proposal (L-1019, 7B, The Nature of Solutions in the Command and Control Problem, 13 August 1962). However, a simpler and more direct approach is the use of a numerical combination.

The "short" unlocking time is not believed to be critical; the time for actual introduction of a reasonable combination can seemingly always be kept shorter than the corresponding time for reception and preparation of the ARM-ENABLE code. In some instances achieving physical access to the weapon may be a severe limitation on reaction time. For this reason the introduction of the code into loaded bombs should be done from the aircraft cockpit and for mounted, erected, or launcher-enclosed missiles it should

be possible of accomplishment through the control console.

The "long" time for unlocking in the absence of the proper key is set by the minimum time (1) to physically bypass the lock system or (2) to discover by trial and error the true combination. The limited-try feature discussed in the References effectively removes (2) from reasonable consideration--not absolutely but with probability as high as desired. The vulnerability burden is thus transferred to deterring or defeating (1); in this area study and experimentation is also being done, e.g. on penalty responses and "impenetrable" membranes.

Basically the desire is to control nuclear bursts rather than the launch of delivery vehicles, because it is necessary to admit as part of the incident problem the possibility of nuclear assemblies being diverted from weapon systems captured, confiscated, or spirited away in politically unstable areas. The operating lock of the PAL device therefore must either be within the basic warhead assembly or be attached inseparably to it. Under these restrictions what the lock physically does to sterilize the system is of considerably less importance than were the PAL switch a general safety device. The PAL system must be engineered to meet a specific threat, namely the deliberate introduction of normal or near-normal arming signals at attainable points of access. It should not simultaneously be attempted to safe-guard against all conceivable combinations of severe environmental inputs and internal malfunctions as conjured for treatment in "classical" nuclear safety problems. The design for the PAL device should meet the following requirements:

1. It must provide a positive block to normal weapon operation against introduction of normal and near-normal input signals introduced anywhere outside the volume protected against penetration for the purpose of bypass.

2. Reliability of operation when activated by ARM-ENABLE inputs through the PAL system should be an order of magnitude better than the expected reliability product for the receipt of the proper ARM-ENABLE code and for proper operation of all other upstream functions in the PAL system.

3. Reliability against spontaneous operation (removal of the block) can be less stringent than 2, provided that this spontaneous ARM-ENABLE does not at the same time externally identify the weapon status.

In connection with requirement 3, some additional features suggest themselves. First, the ARM-ENABLE readout should be designed to operate only when two conditions have been satisfied: (1) that the true ARM-ENABLE code has been correctly introduced, and (2) that the ARM-ENABLE switch has operated. Second, each exercise code should verify that the ARM-ENABLE switch is off before the programmed readout is returned. These features together prevent an unsterilized weapon from being discovered on a routine monitor check and yet, on the introduction of an exercise code, will identify a malfunctioning PAL system and red-line the weapon. On the other hand, emergency introduction of the real code would still satisfy the requirements for live-weapon readout and capability would not be unnecessarily lost.

It is assumed for reasons detailed in Reference 2, that unique programmed readouts are highly desirable for both exercise and real codes. Since PAL must for some time be a probationary system, this is the best means for central monitoring of its workability.

In reference 2 arguments were made for incorporating a primary ARM ENABLE code, a CANCEL code to re-sterilize weapons and return control to central headquarters, plus a secondary (and different) ARM-ENABLE code to circumvent the danger of enemy "spoofing" tactics. Clearly there are several ways in which, following an initial red alert, armed weapons can remain out of headquarters control:

(a) A local commander may, having received the primary ARM-ENABLE code and later the CANCEL code, elect not to disenable his weapons.

(b) A breakdown in communications may prevent transmission of CANCEL codes.

(c) The seriousness of the threat situation may force recourse to the secondary ARM-ENABLE code.

In situation (c) weapons can still be re-sterilized by running out the limited try feature. Clearly this would be done only were all war danger certain to be over for at least the period required to recode all affected weapons. There is no preventative for situations (a) and (b); however, it should be noted that requirements for reporting confirmatory readouts will serve to identify the weapons (and troop units) that are or may be non-compliant.

It has also been suggested that the PAL device might incorporate a timed shut-off so that, following introduction of the ARM-ENABLE code, the duration of the enabled state is time limited and re-sterilization automatically occurs at the end of the set period. While this would overcome difficulty (b) it would tend to aggravate (a) by encouraging weapon commanders to delay introduction of the ARM-ENABLE code. Further, such a feature introduces a measure of uncertainty into the true status of weapons that have been enabled; a local commander, unable to be confident his nuclear ordnance will respond when needed will likely feel forced into firing at the earliest indication of threat before other alternatives are closed out. Indeed, postulating this type of system and its consequences points up dramatically the necessity for the tactical commander to know the future state of his firepower. The absurdity of sitting tight in a worsening military situation with weapons that may revert to duds at any moment is perhaps no more conducive to military blunder than being in the identical situation with known duds awaiting receipt of ARM-ENABLE codes.

In Reference 2 the argument was made that ON-OFF control of PENALTY responses must primarily be at the option of the local commander. Adding these functions to headquarters bookkeeping chores can only compromise the more basic function of the PAL system. The local commander is generally in the better situation to judge the necessity for increasing the degree of the penalty response or for inactivating

this feature if weapons must be withdrawn for surveillance or maintenance.

One disadvantage of this arrangement is immediately apparent--the control codes for penalty responses can be as subject to capture as are the weapons in areas judged to be politically unstable. In consequence, code-controlled penalties can not be regarded as sole protection against tampering with the PAL ARM-ENABLING device. There must instead be incorporated some basic sterilization feature which is permanently on guard and not subject to local control. Any controllable PENALTY responses to be incorporated must be additional and, to the maximum extent, independent of PAL and its first-line self-protective features.

The degree of design integration of PAL functions and PENALTY functions is therefore a hardware engineering rather than an operational problem. Since ON And OFF manipulations of the penalty responses should not be counted in the limited-try register it would seem preferable that penalty codes be introduced through a separate channel. The independent approach, however, still may be second best if the net result is a significant reduction in the overall hardness of design against spoofing, tampering, and penetration. A suitable solution can only be reached through actual development. Two independent lock devices require a larger protected volume and two separate means for coupling-in code signals. This could, as one example, require two connectors--hence two potential soft spots in the protective membrane.

Prognosis

Whatever current emergency plans exist for tactical use of nuclear weapons (for example in Western Europe) they have evolved under the extreme constraints that presently keep these weapons out of the hands of user troops. This means that any plan emphasizing effectiveness of tactical nuclear weapons is almost certain to be unworkable in any sudden, fast-moving campaign. Any plan which is realistic in attention to workability under these constraints is, on the other hand, almost certain to be ineffective. The question is whether a PAL system can sufficiently change these constraints. If it can not, no useful purpose will have been served and, in fact, capability will have been reduced by the addition of one more constraint. If it can, the entire field of tactical nuclear weapon design, development, and operations will be reopened under a new set of ground rules.

The PAL system will itself then enter a true development stage as battlefield intelligence, maneuvers, communications, and emergency plans are invented, tried, and evolved in practice, exercises, and war games. The purpose of PAL is to get the tactical nuclear capability off dead center. Designing PAL as a "safety" device (or to minimum requirements for salability) will no more accomplish this goal than offering new locks for the igloo doors.

C. R. Carlson
Project Supervisor

CRC:es

cys: 1, 2, 3/4A-D. R. Cotter, 9100
4/4A, File