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TECHNICAL REPORT
69-43-CE

BODY ARMOR FOR AIRCREWMEN

by

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January 1969

Project Reference: 1F164204D154 Series: C&ED-50

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FOREWORD

Grateful acknowledgement is made to Mr. George R. Ruggers and Mr. Joseph E. Guilberz, specialists in fiberglass at the U. S. Army Picatinny Arsenal, Dover, N. J. for their contributions to the development of monolithic ceramic composite armor; to Mr. Francis McCourt, U. S. Army Aviation Material Laboratory, Ft. Eustis, Virginia for practical application of the tipping plate armor concept; to Mr. George Stewart, Edgewood Arsenal, for his work in testing armor materials; and to personnel of the U. S. Army Materials and Mechanics Research Center, Watertown, Mass.

Appreciation is expressed to Goodyear Aerospace Corporation, Akron, Ohio, for its pioneering efforts in developing ceramic composite armor; to Mr. Ray Paricio and Mr. Wilbur Herbert, of Coors Porcelain Company, Golden, Colorado, for their assistance in the production of the first monolithic composite; and to the Norton Company, Worcester, Mass., for the development of Boron Carbide armor.

Recognition is also due to NLABS personnel for their contributions: Mr. Robert White, physical anthropologist, and Mr. Richard Burse, engineering psychologist, in the supply of anthropometric data; and Mr. Michael P. Carlucci and Mr. Peter James, clothing designers, in the fabrication of armor carrier prototypes. This work was performed under Project No. 1F164204D154, "Development of Aircrew and Aircraft Armor Protection."

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ABSTRACT

Body armor which protects Army aircrews of low-flying aircraft against 7.62 mm/caliber .30 AP small arms ground fire has been developed by the U. S. Army Natick Laboratories. The armor utilizes a relatively lightweight composite of ceramic bonded to fiberglass. Improvements were achieved on earlier ceramic composite armor made of flat, multiple ceramic tiles by developing separate front and back one-piece composite panels which are curved to fit the torso. A cloth carrier with large front and back pockets was designed to hold the armor panels, permitting the airman to wear the armor comfortably and without interference with his operations. Experimental armor for leg protection against small arms weapons has also been made of this ceramic composite.

INTRODUCTION

Body armor capable of protecting aircrewmen against small arms ground fire first became possible in 1962 when a new material was introduced by American industry. The material, a composite of ceramic backed by multilayer impregnated glass cloth plastic, was effective against caliber .30 AP ammunition. It was light enough so that a protective shield of the material could be worn without excessive discomfort.

The new armor material fortunately appeared just as the need for small arms protection of U. S. aircrewmen was becoming critical in South Vietnam. The helicopter added a new dimension to air mobility as it was used to move troops, artillery and refugees; to support U. S. ground assault operations; to evacuate the wounded, and even to recover downed aircraft. The low-level flights of helicopters, however, brought pilots and crewmen within the range of small arms ground fire. Some of the first American casualties in Vietnam were Army aircrewmen flying reconnaissance helicopters when U. S. personnel were serving as noncombatant advisors. The problem of small arms ground fire increased as more men and helicopters were used and as the weapons and accuracy of the enemy improved.

Armor Prior to the Ceramic Composite

The only body armor items available to the first Army aircrewmen in Vietnam were the World War II Army flyer's flak vest and groin armor and the standard Army M1952 fragmentation protective vest (Figure 1).

The flyer's vests were developed by the Army Ordnance Department during World War II when flights generally were above the range of small arms ground fire and the majority of casualties among airmen were caused by flak, or shell fragments[1]. The vests were composed of overlapping manganese steel plates inserted into a cloth carrier and weighed approximately 17 pounds, 6 ounces[2]. The later M1952 vest, developed during the Korean War, was fabricated of 12 plies of lightweight ballistic nylon and weighed approximately 8.5 pounds[3].

Frequently, pilots in Vietnam laid two of the armor flak vests in the nose bubble of the aircraft and the crew chiefs and gunners sat on extra armor vests[4]. These precautions were unsatisfactory, however, since the armor flak vests were not adequate against the greater penetrating power of small arms projectiles.

The first attempt to protect pilots specifically against the small arms threat came in 1962 after an Army ballistic-protection survey

Army Flyer's Flak Vest

M1952 Fragmentation Vest

Figure 1

team visited Vietnam[5]. The team, headed by the Army Transportation Research and Engineering Command (TRECOM), evaluated various ballistic threats to aircraft, combat troops and vehicles.

As a result of this study, TRECOM designed a pilot's shield made of 1-inch thick Doron, a fiberglass fabric plied and bonded together with polyester resin. These 17.5-pound shields were designed to be held by the airman in front of his chest, with the armor resting on his thighs. The shields were to be used with a system of thin, metal tipping plates which were attached to the center and rear sides of the helicopter or small airplane. The plates were intended to decrease a projectile's penetrating power by tipping the bullet so it would present a larger surface area to the pilot's shield.

The shield and tipping plates were part of a kit which also included seat panels of ½-inch Doron for the sides, bottom and back of the pilot and copilot seats. To meet the urgent requests for armor protection, TRECOM assembled more than 150 of these kits for H-21 and UH-1 helicopters and shipped them to Vietnam by January 1963[6].

Because the weight of armor inevitably compromises payload, fuel or other performance aspects of a helicopter, the military must seek the optimal degree of protection for the least weight. This consideration restricted the use of heavy armor materials, such as Doron and steel, and thus the total aircraft and personnel body area which could be protected. Therefore, lighter protective materials were required.

Armor of New Composite

The development of the relatively lightweight ceramic/reinforced plastic composite material during this period opened new possibilities for small arms protective armor. TRECOM became interested in the new material through the U. S. Army Natick Laboratories (NLABS), which was investigating the potential of the composite for armor. The superior ballistic strength of the composite would make it possible to eliminate the tipping plates and to provide direct protection in seat panels and chest shields[7].

Thus the first body armor made of the composite to reach Army pilots and copilots in Vietnam were chest protectors supplied with the new TRECOM aircraft armor system (Figure 2). The chest protectors were designed like the earlier Doron shields, and were just as uncomfortable and heavy resting on the pilot's thighs. The pilots were unable to wear them for any length of time.

Concurrent with these developments, NLABS was exploring ways to utilize the ceramic composite in armor designed so that aircrewmen could

Figure 2. TRECOM Chest Protector Made of Ceramic/Reinforced Plastic.

wear it comfortably. The first composite armor made by NLABS was a vest designed early in 1962 at the request of the Air Force at Eglin AFB for pilots in Vietnam (Figure 3).

Curved composite tiles of various sizes were shaped to fit into multiple pockets of the vest, which were made from ballistic nylon to reduce ceramic spall. The vest concept proved to have several disadvantages. The seam areas between the ceramic-filled pockets were vulnerable and the heavy plates abraded the inside of the pockets.

NLABS next applied the new material to a curved torso shield[8]. The shield was made of 13 curved, ceramic tiles bonded to a shell which extended from the wearer's collarbone to the groin area. The weight of the shield was supported by an extension which rested on the seat between the pilot's legs. The shield was positioned in front of the pilot by two straps joined to the seat harness (Figure 4).

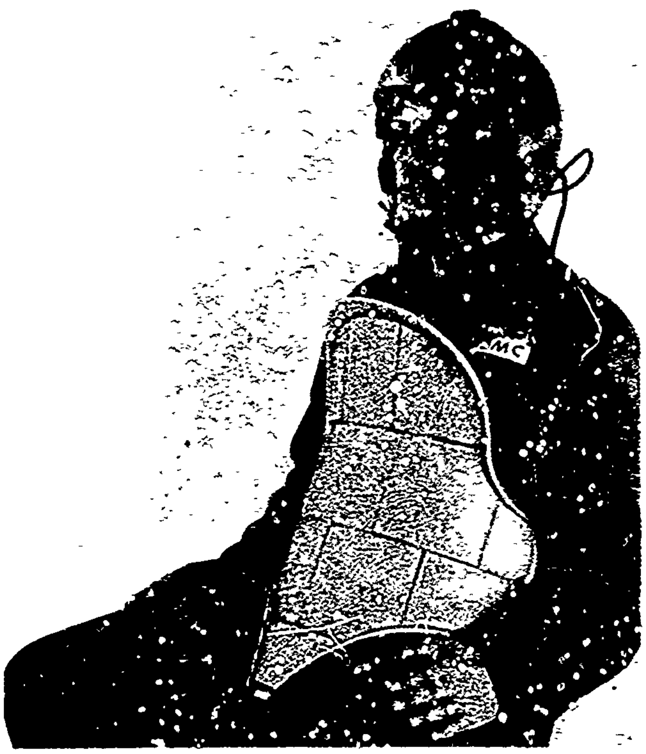
Firing tests at the Ballistic Research Laboratories (BRL), Aberdeen, Maryland, in March 1963, indicated that the torso shield would stop caliber .30 ball and AP ammunition at 100 yards at 0° - 45° obliquity[9]. There was a concern that a caliber .30 bullet defeated by the armor could still cause severe injury to the body by its impact. The Biophysics Laboratory at Edgewood Arsenal, Md., tested the composite and concluded that the force of the impact from a hit would not present a serious problem.

The torso shield was then field tested in Vietnam by the Advanced Research Projects Agency (ARPA). ARPA reported the shield was effective and reasonably comfortable but tended to interfere with the pilot's operation of aircraft controls.

Curved Torso Armor and Carrier. Up to that time, NLABS research efforts in aircrew body armor were somewhat hindered by lack of field data on the problems of small arms protection and armor needs. In August 1964, the Army established a requirement for aircraft and aircrew small arms protective armor. The Army Materiel Command (AMC) assigned the responsibility for development of aircrew body armor to NLABS. The development of aircraft armor was assigned to the Army Aviation Materiel Command (AVCOM) along with TRECOM (now Aviation Materiel Laboratories)[10]. In the fall of 1964 an urgent request was received for small arms body armor for crew chiefs and gunners in Vietnam.

NLABS, in the interim, was developing experimental curved torso and leg armor to be made of the composite. Action was initiated to procure

Figure 3. Experimental Small Arms Protective Vest Developed by NLABS in 1962 for Air Force Pilots, Incorporating Plates of Ceramic Composite in Individual Pockets of Vest.



Experimental Pilot's Curved Torso Shield without Shield Cover, Revealing 13 Ceramic Tiles Bonded to Reinforced Plastic Shell.

Figure 4. Pilot's Torso Shield

Pilot's Torso Shield with Shield Cover, Shoulder Straps and Supporting Extension at Groin Area.

prototypes of the torso and leg units in quantity. The torso concepts included a curved unit made of multiple composite tiles and a curved unit of three rigid sections. The units were designed to be worn in an experimental cloth carrier, T65-1 (Figure 6).

The carrier had large envelopes to contain a front torso piece for the pilot and copilot, or front and back plates for the gunners, who exposed their backs as they moved about the aircraft. The front and back units were attached by adjustable straps to padded shoulder sections. The sides of the carrier were closed by nylon hook and matching pile flaps which permitted size adjustment and quick doffing.

AMC formed a 5-man armor team to visit all the Army aviation units in South Vietnam in February-March 1965[4]. The visit gave team members from NLABS, AVCOM, TRECOM and BRL a chance to gather field data for further armor research.

The team discovered that none of the pilots or copilots were using the TRECOM composite chest protectors as intended, although some of the crewmembers were wiring the shields to troop seats to improvise armor protection. The pilots complained that the weight and positioning of the shield on their laps caused such discomfort and restriction that they preferred exposure to small arms fire.

The AMC team devised a method to modify the 500 available chest protectors so they could be worn on the man. The units were shortened by three inches to fit into a fabric carrier (T65-1) designed by NLABS. Arrangements were made to modify the units and to fabricate the carriers in Vietnam to provide immediate small arms protection.

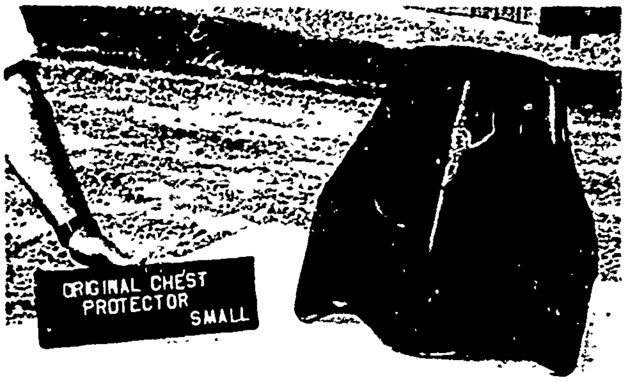
In addition, the new torso and leg armor models were evaluated by approximately 100 pilots and 80 gunners and crewchiefs.

The aircrewmen enthusiastically reported that the new wearable torso armor was comfortable, nonrestrictive and easy to don and doff. The crewchiefs and gunners were especially interested in the carrier idea. Because of their mobility, these crewmembers could not use loose chest protectors or shields attached to the seat.

On the basis of this on-site evaluation, the Army Support Command, Vietnam, (USASCV) requested a quantity of the curved torso armor units with carriers.

A second AMC team visited Vietnam in February-April 1966, to inform Army aviation units of the latest armor developments and to determine if any readjustments in objectives were necessary[11].

Based on the two visits to Vietnam, NLABS improved the armor carrier so that it was more comfortable to wear and easier to operate. Elastic



Flat-Type Ceramic/Reinforced Plastic Chest Protector of Type Supplied to Vietnam in Armor Kits.

Modified Chest Protector in T65-1 NLABS Armor Carrier.

Figure 5. Adaptation of Flat Chest Protectors in Vietnam during 1965 AMC Team Visit.

First NLABS Carrier (T65-1) with Front Plate. Note Wrap-around Velcro Flaps, Snaps at Shoulders.

Improved Carrier (T65-2). Sliding Straps Replace Snaps at Shoulders.

Figure 6. Small Arms Protective Torso Armor Carrier

webbing replaced the non-stretch fabric at the sides, and sliding shoulder straps allowed a more critical adjustment of armor height than the earlier straps with snaps. The new carrier opened only at the right rather than both shoulders, so the front and back units remained joined when the airman slipped the carrier off his right shoulder (Figure 6).

The spall and fragment protective qualities of the carrier also were increased by adding ballistic nylon felt to the shoulder padding and to the inner lining of the plate pockets.

The armor plate itself was made with a new curved, one-piece construction instead of multiple ceramic tiles. The new carrier and armor were flight tested during the second AMC team visit and were readily approved by the users.

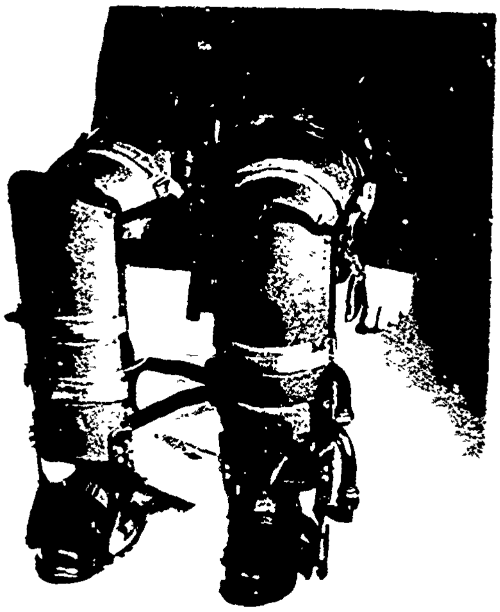
Leg Armor. Gunners and crewchiefs in Vietnam were also very interested in the NLABS leg armor which was demonstrated during the AMC team visits. The armor consisted of frontal thigh and lower leg units which were joined at the knee by an articulating hinge (Figure 7).

The first leg armor was fabricated from dual hardness steel because the composite made with multiple ceramic tiles did not lend itself to critical shaping. Approximately 500 pairs of the steel full-leg armor were delivered to Vietnam early in 1966. Later the development of a one-piece composite construction, which could be shaped to conform to the curves of limbs, made it possible to use ceramic composite rather than steel for leg armor.

The new composite leg armor was flight tested during the second AMC team visit. It was an improvement over the steel leg armor but crewmen reported the clumsiness and weight of the full-leg unit still hindered their mobility. Despite these disadvantages, helicopter crews desired the extra protection, and more than 300 pairs of the composite leg armor were supplied during 1967.

NLABS has since designed a new lower leg unit of the ceramic/fiberglass composite which weighs an average of 18 pounds a pair -- 20 pounds less than the dull hardness steel full-leg armor (Figure 7). The upper thigh unit was eliminated as the major source of weight, discomfort and articulation problems. The thigh unit required a hip harness with straps to stabilize it when the aircrewman stood up. When the man was seated, the armor lay on the upper surface of his thigh and did not protect him from ground fire. The knee hinge posed adjustment problems because of variations in the seated knee height of crewmen(12).

The new single, lower leg unit is anatomically shaped to differentiate between right and left legs (Figure 7). An outward curve at the



Aircrew Member Demonstrates Full Thigh and Lower Leg Armor Made of Dual Hardness Steel. Note Harness for Attaching Armor and Articulating Hinge at the Knee.

Experimental, Single-Piece Lower Leg Armor with Outward Curve at Knees and Differential Shaping For Right and Left Legs.

Figure 7. Small Arms Protective Leg Armor

knee prevents contact between the knee and armor, and provides some protection to groin and upper body areas. A foot bracket serves to stabilize the armor on the leg and to transfer the armor weight from the wearer's leg to the ground. A small quantity of the lower leg units is being procured for testing.

Characteristics of Ceramic Composite

The modern history of the material which made the new body armor possible actually dates back to 1945. That year, Commander A. F. Webster, U. S. Navy, conducted experiments with plate glass placed over Doron(13). The combination proved capable of stopping caliber .30 rifle bullets with much less weight than conventional steel armor.

In 1955, NLABS began applying similar composite principles to lightweight armor vests to protect infantrymen against munitions fragments(14). Various ceramic/reinforced plastic composites were evaluated but they were not effective at weights low enough for body armor.

A new era in small arms protective armor opened in 1962 when industry cut the weight of armor in half with a ceramic composite. This composite, using aluminum oxide ceramic for the front component and Doron for the back, was the first practical armor material capable of defeating caliber .30 AP projectiles at close range. The components of the composite are diagrammed in Figure 8.

The spall shield, which faces the projectile, originally was a coating of polyurethane rubber. NLABS developed the present space shield of ballistic nylon cemented to the ceramic to contain or reduce ceramic and bullet fragments resulting from a hit, thus minimizing the hazards to nearby personnel and equipment from flying fragments.

The next component, the ceramic facing, was fabricated from aluminum oxide for the first armor procurements. Later, industry developed additional ceramics for the facing.

Most of the early back components were fabricated from Doron (a low resin content laminate made of glass cloth with a starch finish and an unsaturated polyester-styrene resin), although a limited quantity were made of aluminum alloy. In 1965, a different reinforced plastic (a woven-roving type) replaced Doron for the backing as a result of materials research at the U. S. Army Picatinny Arsenal. The new backing material increased the penetration resistance of the composite and cost less than Doron. A torso backing made of this reinforced plastic is shown in Figure 9 without the spall shield and ceramic face.

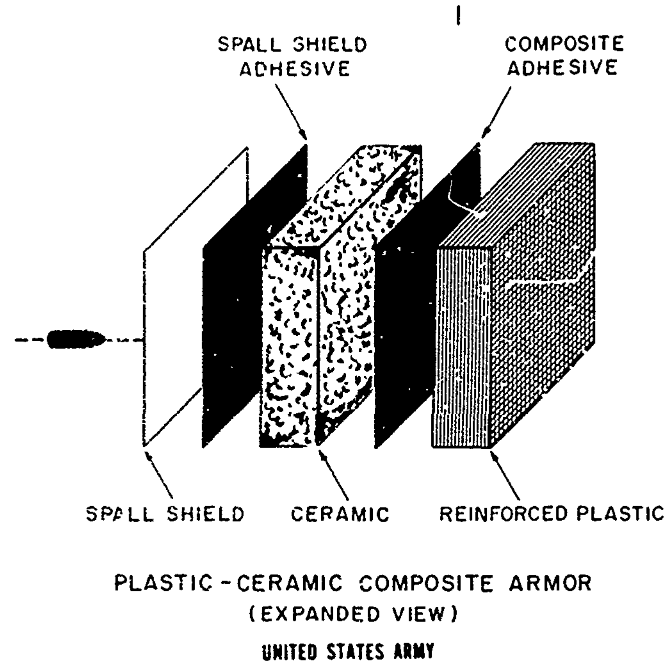


Figure 8. Components of the Armor Composite are, from the left, the Spall Shield which Faces the Projectile; the Spall Shield Adhesive; the Ceramic Facing; the Composite Adhesive, and the Reinforced Plastic Backing.

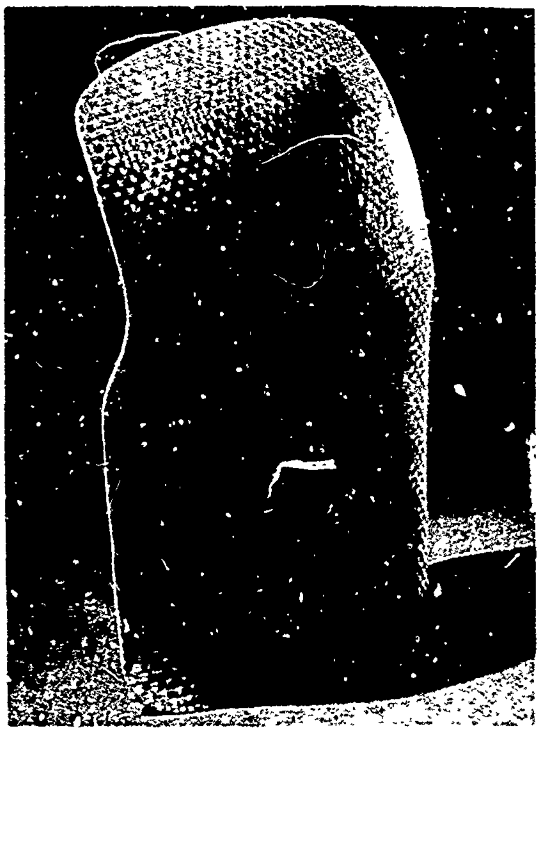


Figure 9. Reinforced Plastic Shell to which Ceramic Facing Is Adhered for Torso Armor Composite

The weight ratio of the ceramic facing to the reinforced plastic backing is not particularly critical. For caliber .30 protection, the backing is roughly one-third of the total composite weight and ¼-inch thick. The adhesive which bonds the front and back components may be a two-part, solventless polyester-polyurethane or polysulfide. Until recently the ceramic front was adhered to the backing after the reinforced plastic was molded into shape. Now the two components are bonded together while the backing is being molded.

The combination of ceramic and reinforced plastic is effective at a much lower weight than either of the materials alone, or any other single material of equal weight. The composite acts on ball and armor-piercing projectiles with a slight variation. Ball projectiles are shattered at impact into fine particles which spew out of the crater formed in the ceramic. With armor-piercing bullets, the jacket is stripped off and the projectile is broken into pieces. In both cases the back component stops and/or contains the projectile pieces.

The damage produced by bullets on aircrew torso armor is fairly localized, as can be seen in front (Figure 10) and back (Figure 11) views of the armor. On the fronts, the inner circle where the ceramic has been completely expulsed by the bullet is approximately one inch in diameter. The outer circle of fractured but adherent ceramic is approximately 4 inches in diameter. Individual cracks may extend further, depending upon the ceramic's size and shape, and the impact location.

The reinforced plastic shell behind the shattered ceramic may be "unaffected" by the bullet, as in the area indicated by the arrow in Figure 11, or the backing may be bulged or delaminated, depending on the severity of the ballistic impact.

The ballistic efficiency and design of the composite material have been significantly improved since its first use. The greatest progress has been achieved in the ceramic component. Initially, the ceramic facing consisted of individual flat, 6-inch square tiles adhered to the reinforced plastic back. These tiles had to be made with raised edges and carefully hand-fitted onto the shell to minimize ballistic weakness at the joints.

Further development by NLABS and industry led to curved ceramic tiles which made it possible to shape the shields more closely to the human torso. The curved armor fit more comfortably and was lighter because of its reduced surface area.

By the summer of 1965, the ceramic was made in single torso-size, curved plates. The technology for the monolithic ceramic was conceived and developed by armor specialists at NLABS and Picatinny Arsenal[15].

Effect of Bullets on Aircrew Armor

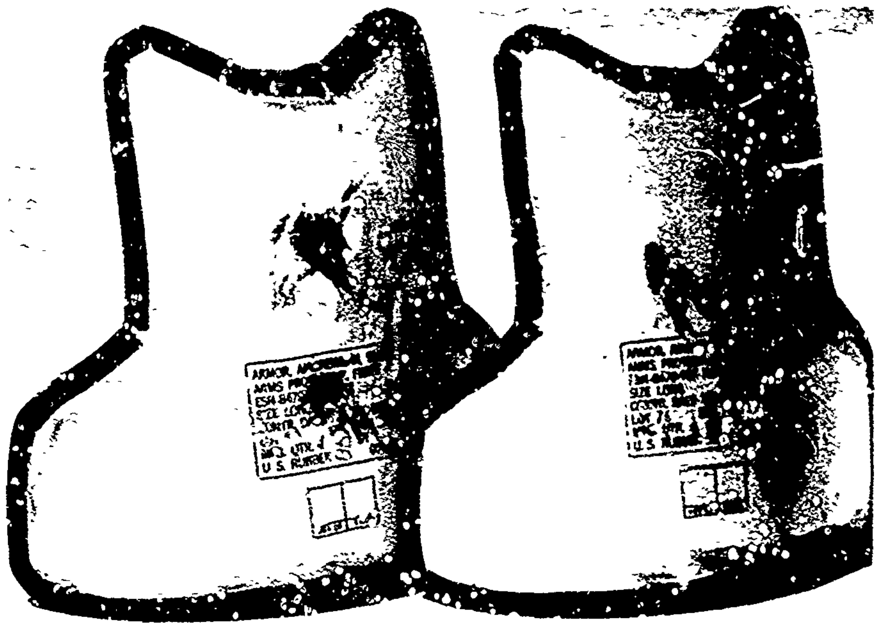


Figure 10. Front View of Composite Torso Fronts (Monolithic Ceramic) Removed from Fabric Carriers. Caliber .30 AP Bullets Penetrated Spall Shield, Formed Craters in the Ceramic Facing and Fractured the Surrounding Ceramic.

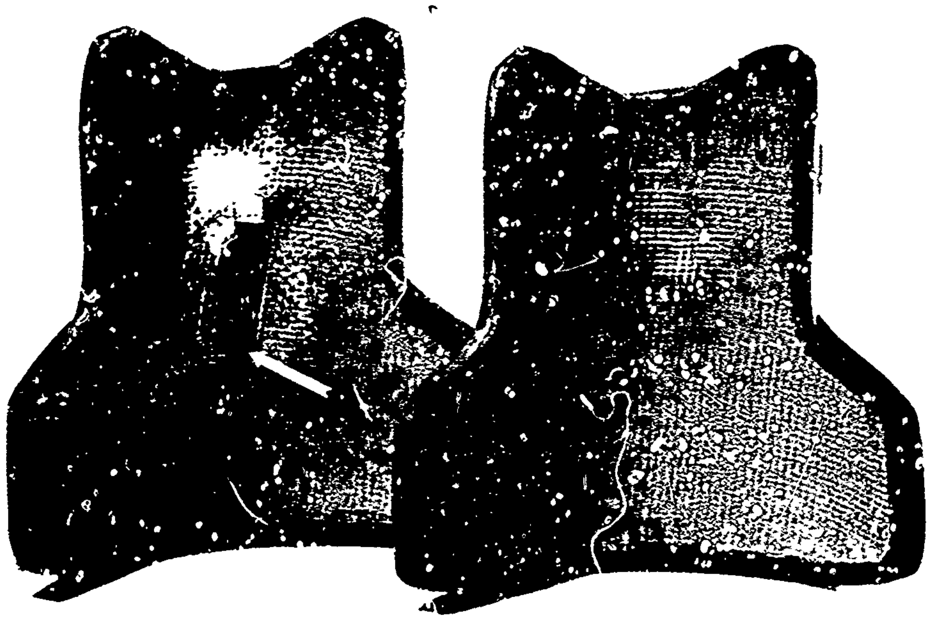


Figure 11. Back View of Torso Fronts, Shown in Same Order Without Fabric Carriers. Reinforced Plastic Backing at left Was Not Visibly Damaged by Lower Hit Near Arrow But Shows Bulging from Upper Hit.

The new monolithic ceramic strengthened the composite by eliminating the multiple tiles which were ballistically weaker at the joints than the edges by several hundred feet per second. The one-piece ceramic also expanded the possibilities of armor protection because it could be shaped to follow the more complex curves of limbs and vital aircraft equipment, thereby reducing bulk and weight of the required armor.

New materials have been used for the ceramic, in addition to aluminum oxide, to meet the rising production demand and to reduce the weight of the ceramic component. Torso sets of boron carbide and silicon carbide, weighing one to three pounds less per set than alumina, were initially procured in 1965. The weight of boron carbide and silicon carbide armor (with the spall shield) is 22% and 10% less, respectively, when compared to aluminum oxide armor.

However, the carbides are at present two to four times more expensive than the alumina because they cost more initially and are more difficult to fabricate into armor. The boron carbide, made at first with individual tiles, is now produced in a monolithic form similar to the alumina. The silicon carbide fronts must be made in a two-piece construction using left and right halves because of the maximum piece width that can be produced in existing tube furnaces.

Investigation of other ceramic materials continues. One promising ceramic is a combination of boron carbide and silicon carbide which is effective in a weight between the two materials. Other potential candidates being studied by industry are beryllium oxide and silicon nitride.

The contributions of aircrew armor to military efforts are very real but di[illegible]ult to substantiate. Certainly the armor has increased the effectiveness of air rescue teams under enemy fire and the overall tactical utility of air cavalry by promising some protection to aircrews and pilots.

Actual statistics on the number of wounds or fatalities prevented by the armor have been difficult to collect because of the rapid medical evacuation of the wounded and the pressures of combat. Casualties often are evacuated before information on the type of armor worn, the protection provided by the armor, the nature of the wounding agent, the range of fire and other factors can be reported. Such information then becomes a matter of speculation.

Despite these difficulties, the U. S. Army Vietnam (USARV) obtained data on 72 aircrew casualties occurring from July 1966 through June 1967 -- a small but fairly representative sample since cases were reported from every sector of South Vietnam and almost every type of aviation unit[16]. The data revealed that 76.4 percent of the 72 airmen wore the torso armor and in several cases the armor clearly prevented serious injury or death. Further, the extremely low incidence of wounds to the chest and back (3.6 percent of the total) was attributed to the protection of the torso armor and armored seats.

In contrast, the lower extremity accounted for 40 percent of wounds to the 72 casualties. Nearly half of these occurred to the lower leg and knee -- a disproportionate frequency for the body area exposed. Aircrews reportedly were not using the steel or composite full leg armor because of its awkwardness. The improved, experimental lower-leg armor was not available.

Current Development Program

Increase in Protection. The rapid progress in the art of small arms protective armor since its beginning in 1962 has enabled the Army to raise its objectives for body protection. Aircrew armor now protects against direct as well as oblique hits of caliber .30 AP at 100 yards. It is hoped caliber .50 protection will be possible at a later date.

In the 1967 USARV study, the projectiles which caused the majority of the casualties were caliber .30 bullets or 7.62 mm ammunition[16]. Nearly half of the cases were wounded by intact bullets. However, 30 percent were wounded by fragments from shattered bullets. Such secondary missiles, a frequent cause of minor injuries, may also inflict severe wounds because of their size and sharp, irregular edges. Airmen have lost an eye to fragments ricocheting off the aircraft components and body armor[17].

A current goal is to increase spall and fragment protection. To a degree such protection is provided by the ballistic nylon covering the face of the composite plates, and by the ballistic nylon felt in the shoulder padding and plate pocket linings of the carrier. This protection is not adequate, however. The USARV study reported that 30.5 percent of the 72 airmen studied wore an M1952 vest over or under the torso armor. On the basis of such data, USARV recommended that fragment and small arms protection be combined in one vest to eliminate the discomfort and bulkiness of two items.

NLABS had anticipated this need early in 1967 when it designed a vest-like carrier for Air Force UC-123 crews engaged in low-flying defoliation operations in Vietnam. The vest was made of a layer of ballistic nylon felt and two plies of ballistic nylon. The fabric combination not only defeats spall and shell fragments, but also reduces the ricocheting of fragments by retaining projectile splash and ceramic spall. The high collar, also made of felt and ballistic nylon, provides a high degree of protection to the neck area. The fabric combination extends the fragment protection of the T65-2 to the neck, upper right and left chest areas, the lower back, sides and lower abdomen (Figure 12).

For this additional protection, the experimental carrier adds 5 pounds to the present body armor system -- approximately 4 pounds less than the M1952 vest -- and, as a single item, is much more comfortable than the combination of torso armor and M1952 vest.

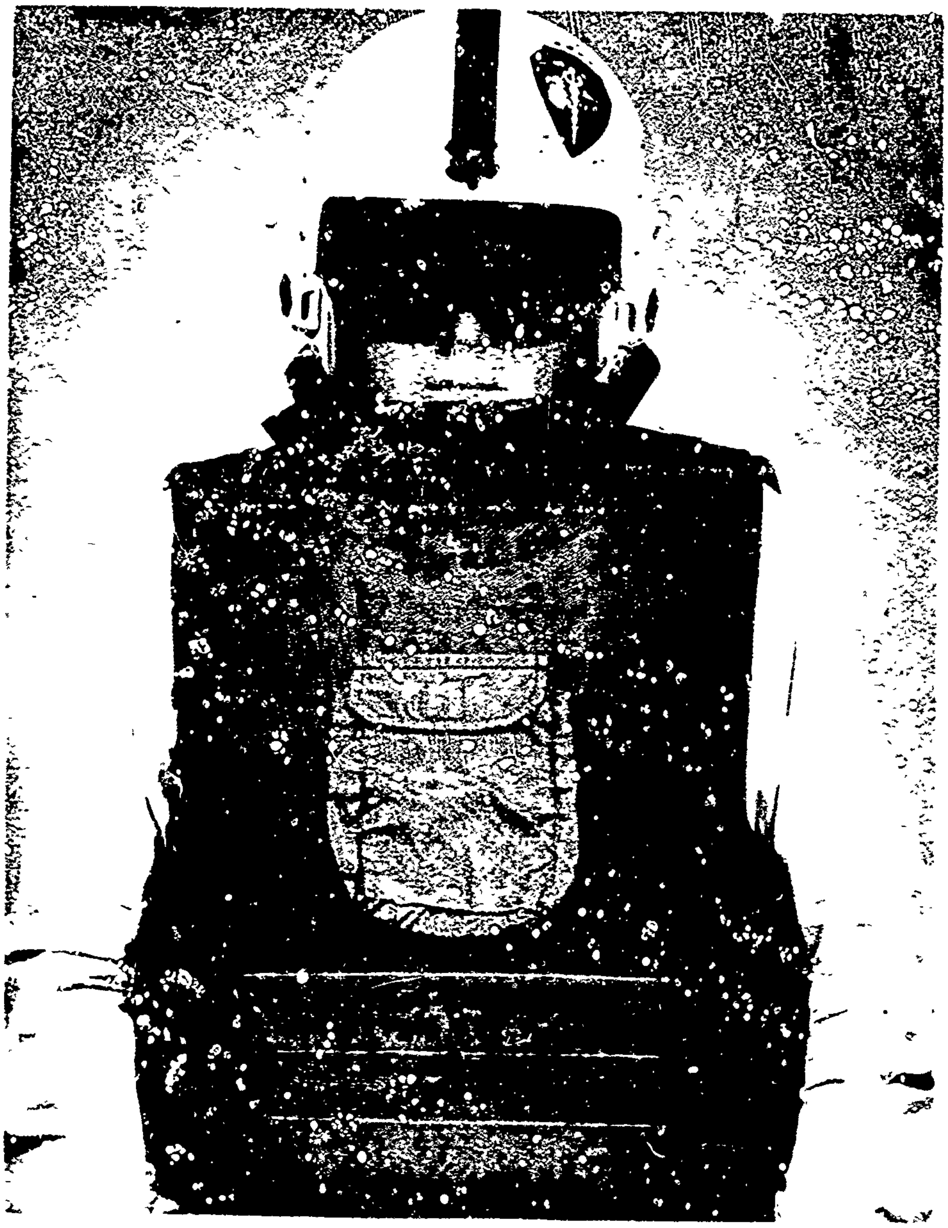


Figure 12. Aircrew Body Armor Vest Developed by NLABS for Air Force UC-123 Crews Combines Fragment, Projectile Splash and Caliber .30 AP Protection.

NLABS has also used the ballistic nylon and nylon felt in an experimental 3-pound diaper-like garment for groin and buttocks protection from spall and fragments. Leg coverings of the ballistic fabrics are being considered.

Design and Comfort Improvement. The present sizes of short, regular and long torso units are based on a tariff worked out at NLABS to expedite production of the first armor.

To improve the fit and comfort of body armor, a new sizing system is being drawn up under contract[12]. Because conventional sizing systems are set up for flexible, enclosing garments, a special system is needed for rigid armor units.

Anthropometric data gathered by NLABS and the Air Force have been analyzed to determine the body dimensions most relevant to the proper fitting of torso and leg armor. Four torso sizes (two widths for each of two torso lengths) and two leg armor sizes (two length and width combinations) have been proposed. The new sizing system will be implemented as production adjustments are made.

The comfort of the armor also will be improved by anatomical shaping. Existing armor is curved with a uniform radius in horizontal and vertical directions. The contractor has developed molded torso armor with compound curves which reflect the body contours of the upper chest and back more closely[18]. The contoured armor provides increased side and peripheral protection. New lower leg armor also incorporates the anatomical shaping.

Compatibility of Armor and Aircraft. As new body armor is developed, it must be coordinated with aircraft armor and aircraft designs. In May 1967, the U. S. Army Human Engineering Laboratories, Aberdeen, Md., began a study of the interior design and work performance requirements of all Army aircraft from the present through aircraft planned for 1975. The study will guide NLABS technologists in developing body armor which does not hinder the airman in his flight duties. The aircraft and body armor systems will be coordinated for each aircraft to minimize the weight penalty.

Another aspect of the compatibility problem is the performance of body armor in the event of an aircraft crash. The body armor must not interfere with the escape features of the particular aircraft, such as ejection seats, door exits and parachutes. Little is known about the effects of body armor on the airman if he cannot doff it before crashing. In May 1967, a contract was awarded for testing the crashworthiness of existing and experimental body armor items.

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AD [illegible]

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D	
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)	
1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Natick Laboratories Natick, Massachusetts 01760	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP
3. REPORT TITLE BODY ARMOR FOR AIRCREWMEN	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Summary Report, 1962-1967	
5. AUTHOR(S) (First name, middle initial, last name) Edward R. Barron Anthony L. Alesi and Alice F. Park	
6. REPORT DATE January 1969	7a. TOTAL NO. OF PAGES 22 / 7b. NO. OF REFS 19
8a. CONTRACT OR GRANT NO. b. PROJECT NO. 1F164204D154 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 69-43-CE; C&ED-50 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U. S. Army Natick Laboratories Natick, Mass. 01760

13. ABSTRACT

Body armor which protects Army aircrews of low-flying aircraft against 7.62 mm/caliber .30 AP small arms ground fire has been developed by the U. S. Army Natick Laboratories. The armor utilizes a relatively lightweight composite of ceramic bonded to fiberglass. The U. S. Army Natick Laboratories improved on earlier ceramic composite armor made of flat, multiple ceramic tiles by developing separate front and back one-piece composite panels which are curved to fit the torso. A cloth carrier with large front and back pockets was designed to hold the armor panels, permitting the airman to wear the armor comfortably and without interference with his operations. Experimental armor for leg protection against small arms weapons has also been made of the ceramic composite.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Protection	8		4			
Military personnel	9		4			
Aviation personnel	9		4			
Torso	9		4			
Small Arms	9		4			
Antipersonnel weapons	9		4			
Body armor	10		9			
Development			8			
Design			8			
Fiberglass	10		9			
Ceramics	10		9			
Bonding						

Unclassified

Security Classification