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EVALUATION OF THE SIERRA ENGINEERING Company LIGHTWEIGHT HELMET

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NOTICES

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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Lightweight Helmet Evaluation
Aircrew Equipment

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report covers the advanced development of a lightweight helmet (LWH) designed by Sierra Engineering Co. which has recently been evaluated as a candidate for reducing the stress and strain on the neck of aircrewmembers exposed to sustained high levels of positive acceleration ($+G_z$).

Under the general guidance of the ASD Life Support Systems program officer (ASD/AEL) and with the assistance of the Tactical Air Warfare

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Center and the ASD/AEL, the Aerospace Medical Division (AMD) conducted an evaluation of the Sierra LWH which was divided into two broad phases: laboratory qualification (Phase I) and flight testing (Phase II).

During Phase I, Sierra provided ten helmets for testing: six LWHs for the contractor-performed testing of impact and penetration resistance, acoustic attenuation, and windtunnel/antilift characteristics; and four LWHs for USAF-conducted assessments relevant to fit, maintainability, retention/pressure breathing, fixed visual fields, altitude, thermal, acceleration, voice communications effectiveness, chemical-defense equipment, and cockpit compatibility. The HGU-26/P was used as the basis for comparison. During these evaluations, problems were noted in the areas of mask retention, which in turn caused difficulties with pressure breathing and mask slippage during $+G_z$; and fit, which led to visor/spectacle interference and visor/mask incompatibility. Improvements over the standard USAF HGU-26/P found during the USAF assessment included decreased weight, improved stability during sustained $+G_z$, and during sustained windblast, decreased aerodynamic lift, improved peripheral vision, improved head mobility in the upward vertical plane, and decreased maintenance. Phase I data were used to make improvements in the Phase II helmets.

During Phase II Sierra provided twenty helmets for flight testing at Nellis AFB in the AIMVAL/ACEVAL program. These helmets were flown in both F-5 and F-15 aircraft. During these evaluations, problems were noted in the areas of liner comfort, chinstrap comfort, and integration with full-length bayonets. Although the helmet was not found acceptable from a comfort/fitting standpoint, the louvered visor cover and flattened side portions of the shell, which reduced aerodynamic lift, were considered a major advance in helmet design. This was in addition to the lower profile, improved peripheral vision, and excellent stability under high G.

PREFACE

The authors wish to gratefully acknowledge the professional consultation, inhouse and on-site assistance provided by staff members of the Aerospace Medical Research Laboratory (AMRL), School of Aerospace Medicine (SAM), Aeronautical Systems Division (ASD/AEL), Tactical Air Warfare Center (TAWC), and the AIMVAL/ACEVAL crewmembers and Life Support Group at Nellis AFB, Nevada. More specifically, this technical report was made possible by the cooperative efforts of: Mr. Jim Brinkley, Dr. Charles Nixon and staff (AMRL); Mr. Ken Troup and Mr. John Hockwald (ASD/AEL); Sgts Frank Haddock, Charles Colley, Juan Moran, Arnott Moore, William Bentley, and other chamber technicians and subjects, Mrs. Joyce Keller, and Miss Marion Green (USAFSAM); Capt Phillip Templin (TAWC); and Capt Johnson and Life Support staff at Nellis AFB, Nevada.

EVALUATION OF THE SIERRA ENGINEERING COMPANY LIGHTWEIGHT HELMET

INTRODUCTION

The generation of fighter aircraft now entering the military inventory places increased stresses upon the aircrewmember. These stresses are a direct result of the increased performance of these new weapon systems. Experience gained to date in the operation of these sophisticated fighter aircraft has revealed a pressing need for new personal protective equipment which permits the operator to function effectively in flight. In particular, this report covers the advanced development of a lightweight helmet (LWH) designed by Sierra Engineering Co., which has recently been evaluated as a candidate for reducing the stress and strain on the neck of aircrewmembers exposed to sustained high levels of positive acceleration ($+G_z$). In addition to reduced weight, the helmet also incorporates low profile, minimum bulk, improved peripheral vision, an integrated chin/nape strap, and reduced aerodynamic lift (Fig. 1).

In a coordinated effort the Aerospace Medical Division (AMD), Aeronautical Systems Division (ASD/AEL), and the Tactical Air Warfare Center (TAWC) conducted an evaluation of the Sierra LWH which was divided into two broad phases: laboratory qualification (Phase I) and flight testing (Phase II).

During Phase I, Sierra provided ten helmets for testing: six LWHs for the contractor-performed testing of impact and penetration resistance, acoustic attenuation, and windtunnel/antilift characteristics; and four LWHs for USAF-conducted assessments relevant to fit, maintainability, retention/pressure breathing, fixed visual fields, altitude, thermal, acceleration, voice communications effectiveness, chemical-defense equipment, and cockpit compatibility. The HGU-26/P was used as the basis for comparison. During Phase II Sierra provided 20 helmets for the TAWC/ASD flight trials at Nellis AFB in the AIMVAL/ACEVAL program. These helmets were flown in both F-5 and F-15 aircraft.

PROTOTYPE DESIGN FEATURES

The following discussion describes the prototype helmet as it existed before Phase I.

Helmet Shell

The helmet shell was fabricated from an epoxy resin reinforced with Kevlar aramid cloth, selected for its low weight/high strength properties. The silhouette, or width, was reduced by flattening the sides of

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the shell; the trimline was changed to provide increased peripheral vision to the user. The shell weight was [illegible] grams compared to 373 grams in the standard HGU-26/P.

Figure 1. The Sierra lightweight helmet (LWH) and MBU 12/P mask.

Liner

The composite, rigid, polystyrene/urethane foam form-fit liner used in the prototype weighed 130 grams, although varying head sizes resulted in varying weights.

As an alternative to the form-fit liner, a precast semiresilient open cell foam liner was also offered.

Aerodynamic Visor Housing

Recent statistics demonstrate an average helmet loss rate of 16%. Reportedly, helmet loss during egress is initiated by a lifting action of the helmet, followed by a forward rotation, which eventually results in loss of the helmet, thus removing head protection from the crewmember for the continuation of his escape.

It has been calculated that the average helmet is subjected to a lifting force of about 450 pounds at an estimated airspeed of 600 knots. Elimination or reduction of this force would inhibit the forward rotational movement of the headgear because of increased interface between head and helmet interior. Since the helmet/visor housing basically acts as an airfoil, generation of lift is to be expected. The lift can be removed or minimized by "stalling" the helmet airfoil. This stall effect can be achieved by disrupting the flow over the airfoil.

To this end, the visor housing was equipped with multiple integral "louvers," or spoilers, which deflect the incoming frontal flow upward causing the helmet to press down onto the head. The rear side of the louvers has an opening that allows the "ram air" scooped up by the opening between helmet visor and visor-housing to escape through the vents. A significant reduction of lift was anticipated.

Helmet Retention System

In support of the efforts noted in the previous paragraph, a novel integrated chin and nape strap was incorporated in the helmet. The construction of this device is akin to that of the "Chinese Finger Cuff," which delivers an increase in retention forces equal to those causing removal of the helmet.

Earcups

Silicone rubber earcups were utilized in lieu of the customary hard plastic earcups currently in use. The resiliency of these units offered greatly improved comfort and was made necessary by the reduced silhouette, or width, of the shell.

Earseals

The standard vinyl earseals become hard as they age and eventually crack. These earseals require replacement and detrimentally affect the sound attenuation capabilities. They were replaced by polyurethane earseals.

Communications

The standard H-143 earphones weigh 64 grams per pair and were replaced by new lightweight H-143 earphones weighing 36 grams per pair. This was a weight reduction of 28 grams, or 43.7%, while the same audio qualities were maintained.

Visor Knob

A "Rapid Action Knob" was designed to permit instant locking or unlocking of the visor lens; the rotary motion of the HGU-26/P helmet visor knob was thus eliminated. The natural rest position of the spring-loaded knob is the locked position for the lens. To move the lens, a quick squeeze of the knob with either left or right hand provides the desired action. The top surface of the knob is covered with a protective cushion to prevent damage to the aircraft canopy.

Receiver Mechanism

The weight of the standard receiver mechanism was considered unacceptable, and efforts were undertaken to minimize the weight without sacrificing the strength. The cast metal housing was eliminated, and its protective function was taken over by extending the visor housing downward over the actual retention mechanism. This action not only improved the esthetics, but also lowered the profile and reduced the weight. Rotary adjustment of the receiver facilitates adjustment to varying individual facial features.

LABORATORY QUALIFICATION (PHASE I)

Phase I consisted of three subphases: (1) advanced design and fabrication of test helmets by the contractor; (2) design tests by the contractor and by the Air Force; and (3) modifications to the design based upon the results of the tests.

Advanced Design and Fabrication of Test Helmets

The prototype helmet was hand fabricated as no tooling existed at the onset of Phase I. The advanced design included refinement of the medium-size helmet and the development of parameters for a large-size helmet. Both medium- and large-size helmets were fabricated.

The prototype medium-size shell was molded using a mold for the HGU-26/P with metal inserts to achieve the flat ear sections. The maximum outer width of the shell was 21.8 cm (8.6 in.). With the silicone earcups slightly compressed, as during use, the distance between the earcups was 15.0 cm (5.9 in.). Table 1 shows this to be approximately a 93rd percentile bitragion diameter. Although this figure seemed high for a medium-size helmet, all early indications were that the medium-size prototype fit was similar to that of a medium-size HGU-26/P helmet.

TABLE 1. PERCENTILE VALUE BITRAGION DIAMETER[a]

%	mm	in.
85	147.6	5.81
90	149.0	5.87
95	151.0	5.94
97	152.4	6.00
98	153.4	6.03
99	154.8	6.09

For the large-size helmet, 15.5 cm (6.10 in.) was chosen as a suitable distance between the earcups. Since the same earcups and lining are used in either size helmet, the outer shell width was calculated for the large-size helmet by adding the difference between the outer and inner dimensions for the medium-size helmets to the inner dimension for the large helmet. An outer shell width of 22.4 cm (8.8 in.) was thus determined for the large-size shell.

The trimlines for both size shells were based on the trimlines for the HGU-26/P. In order to increase the visual field, the trimlines were raised 6.3 mm (1/4 in.) at the center of the browlines and at the center of the napelines. The browlines were given a gullwing shape.

Early in Phase I, in an effort to improve the marginal penetration resistance of the Kevlar shell, experimentation with different resins was undertaken. A slightly lower strength resin was tried to take advantage of the high tensile strength of the Kevlar. Three test panels were made (of Kevlar 181 preimpregnated with polyester resin) to test the effects of mold parameter variations. Following this, a sample Kevlar helmet shell was molded using the same material. In order to provide data for comparison to earlier tests, this shell was subjected to MIL-H-83147 impact and penetration tests. Since this shell

[a] Hertzberg, H. T. E., et al. Anthropometry of flying personnel - 1950, Sept 1954 (AD 047 953).

compared favorably with other trials, it was retested to ANSI Z90.1 1971/Z90.1A-1973 specs (between the previous impact points), and it passed on the first impact (second impact was not tested). This resin system was used on the four helmets supplied to USAF later in Phase I.

During the course of Phase I certain techniques were developed for machining irregular surfaces composed of Kevlar laminate. Drill holes require special cutting bits and backup fixtures. Edge trimming could be improved with special cutting blades, but ragged edges were still nearly inescapable and had to be covered or meticulously hand worked.

An optimization of the visor housing configuration (Fig. 2, Configuration B-2) by classical aerodynamic analysis was attempted to determine the most effective position and angle of the louvered lift spoilers. Air flow visualization over the top of the helmet was undertaken at Sierra Engineering Co. in April 1976. Smoke flow methods were inconclusive, but tissue streamers attached to several points on the helmet exterior indicated flow disruption when a conventional spoiler was located along the rear edge of the visor housing. Under these conditions, the streamers were pulled away from the surface of the housing. Based upon this finding a crescent-shaped spoiler was added to the louvered configuration visor housing of the helmets delivered by Sierra Engineering Co. in Phase I (Fig. 2, Configuration B-1).

A third visor housing configuration (Fig. 2, Configuration B-3) was developed just prior to the windtunnel tests. This configuration was named the Sierra Anti-Lift Loop.

Design Tests by the Contractor and by the Air Force

Test Background--Noise attenuation tests on the Sierra Lightweight Helmet were conducted by the Audiology Center of Redlands Medical Clinic Incorporated, Redlands, California. The helmet was equipped with two elastomeric earcups and polyurethane earseals. The purpose of this study was to determine the real-ear attenuation characteristics at threshold of the prototype helmet using precast and custom-fit liners. The study was performed in accordance with specifications set forth by the American National Standard Institute (ANSI STD Z24.22, 1957.)

Windtunnel studies were conducted at the Vought Company, Dallas, Texas. It was the purpose of this test to determine the forces and moments acting on a helmeted head in a sustained windtunnel condition. The tests consisted of measurements taken with the test helmet mounted on an anthropometric dummy strapped into an ACES-II ejection seat. Data were taken comparing the HGU-26/P standard protective helmet and the Sierra helmet with several different visor housing configurations. An additional windblast test to validate retention characteristics of the

Sierra helmet in a high windblast environment was conducted using Air Force facilities located at Wright-Patterson AFB, Dayton, Ohio.

The impact and penetration tests were conducted inhouse by Sierra Engineering Co. Impact tests were conducted in accordance with the ANSI Z90 standard as modified by military specifications. Penetration tests were conducted in accordance with MIL-STD-H83147.

Six subjects were chosen for those tests conducted in the Air Force facilities. The subjects covered the largest available anthropometric size range that would fit the test helmets. Two subjects wore the medium-size LWH and four subjects wore the large-size LWH.

The assessments performed by the Air Force included fit, maintainability, retention/pressure breathing, fixed visual fields, high altitude breathing, thermal tests, acceleration tests, voice communications effectiveness, chemical defense equipment, cockpit compatibility assessment, and subjective/observer evaluation.

Noise Attenuation Test--This study was performed in accordance with specifications set forth in the Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold (ANSI-Z24.22, 1957). The only exception was that the test signals were frequency-modulated tones instead of unmodulated tones; this was done to minimize standing wave interactions in the sound field. All measurements of ambient noise, interior room characteristics, etc., met or exceeded requirements of the above standard.

A single prototype medium-size LWH with the epoxy resin system was used for all subjects tested throughout the entire study. Each subject was measured for head size to assure that the helmet was of the proper size. Subjects were tested while wearing the helmet equipped with the precast liner (same liner for all subjects) and with a custom-fit liner that was specially fabricated prior to the study (different liner for each subject).

All testing was performed with the visor retracted into the helmet shell. The helmet and liners were fitted to each subject by Mr. Duane Cowgill of Sierra Engineering Co. before each session. The fitting procedure included selection and application of detachable foam inserts between the earcups and helmet shell to assure maximum sound attenuation. Care was taken to prevent a fit so tight as to make the helmet uncomfortable. The foam inserts were available in two sizes.

Ten young adults served in this study. Each subject passed a pure-tone screening test from 125 to 8000 Hz in both ears at 15 dB (ANSI, 1969) using a standard clinical audiometer. Each subject completed a practice session lasting approximately one hour prior to testing during the study. This practice session consisted of instructions and familiarization with the threshold task required at representative test frequencies. Subjects were paid for their participation in this study.

Symbol	Definition
B-1	Lightweight helmet with visor housing No. 1

B-2	Lightweight helmet with visor housing No. 2

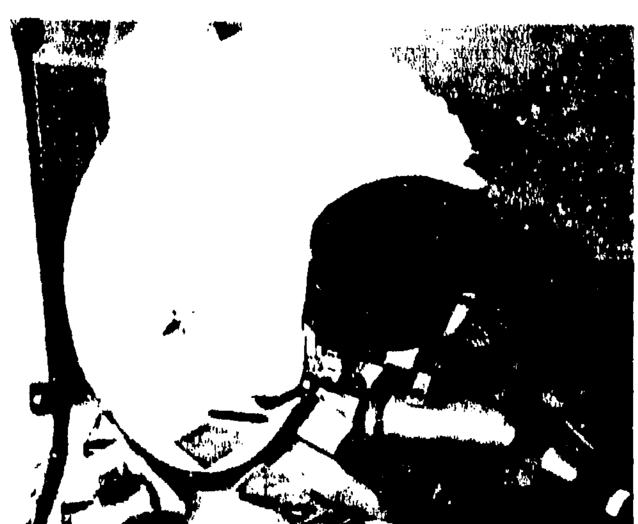
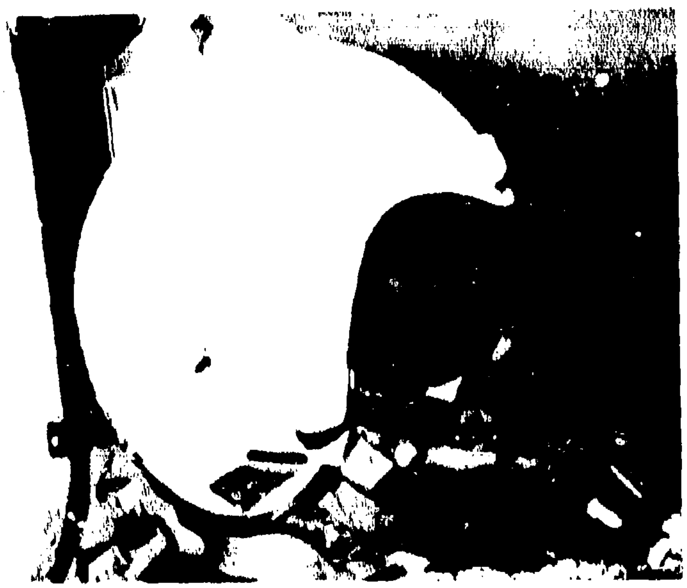


Figure 2. Helmet configurations used during the wind tunnel tests.

B-3 Lightweight helmet with visor housing No. 3



B-4 Standard helmet w'*. standard visor housing

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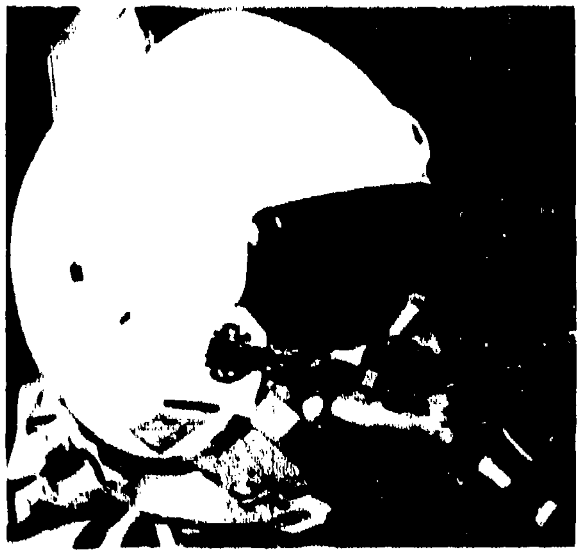
BA Lightweight helmet with visor housing used on helmet A



A1 Standard helmet and visor with a transverse ridge across top of helmet

Ridge height varies from 2.54 cm (1 in.) at sides to 4.57 cm (1.8 in.) at top of helmet. Ridge was fabricated from 0.97-cm (3/8-in.) thick plywood.

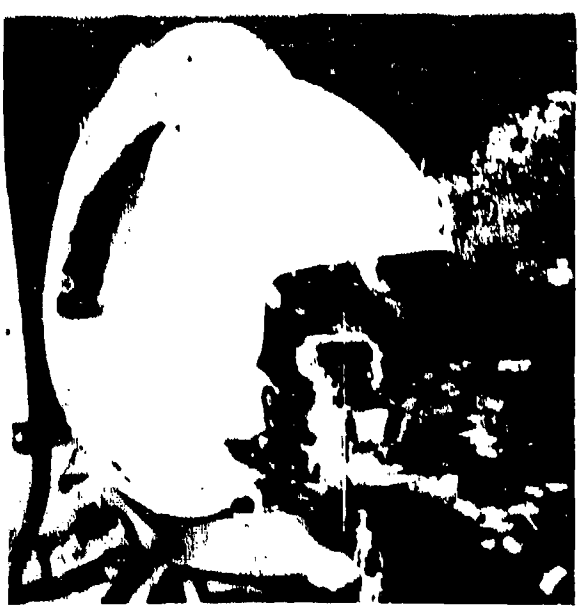
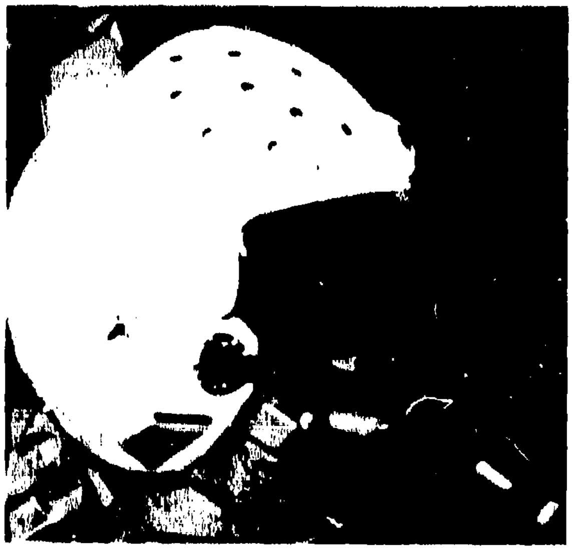


Figure 2. Cont'd

BH Configuration BA with holes in visor housing



BAUV Configuration BA with visor in up position
(holes were closed with aluminum tape)

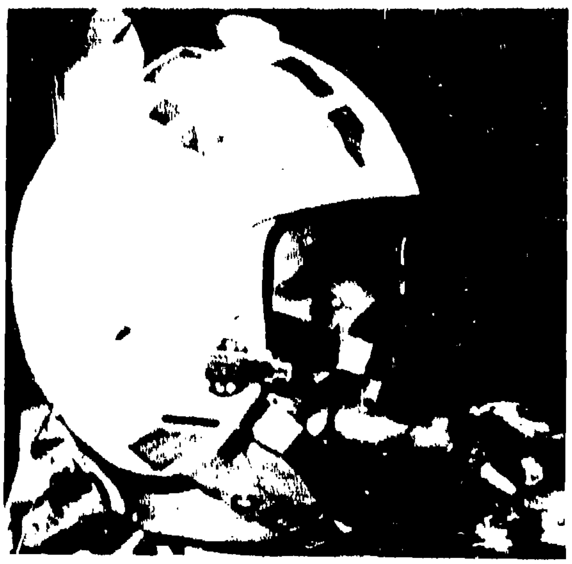


Figure 2. Continued.

All reference thresholds (without helmet) and test thresholds (with helmet) were obtained in a sound-treated room (Industrial Acoustics Co., model 1200) that meets specifications for background noise in audiometric test rooms (ANSI - S3.1, 1960). All test equipment except the subject chair, subject response switch, and loudspeaker were located outside the test room.

Five percent frequency-modulated pure tones from 125 to 8000 Hz were used to measure the real-ear attenuation of the LWH. All test signals were 300 msec in full-amplitude duration with 20-msec rise-decay times.

Each subject participated in a total of six sessions to complete the entire study. Each session consisted of obtaining both reference thresholds and test thresholds at all test frequencies. Half of the subjects were tested wearing the helmet with the precast liner during the first three sessions and the helmet equipped with the custom-fit liner during the last three sessions. The remaining half of the subjects received the reverse order of testing with respect to helmet liner type. The nine test frequencies were randomly selected during each session. The subject's head was located approximately 1 meter from the center of the loudspeaker in a head-positioning device during all sessions. Subjects were given brief rest periods between sessions and were required to leave the subject chair and to remove the helmet, if appropriate. Subjects were then required to again fit the helmet prior to obtaining test thresholds during the subsequent session. Each subject adjusted the helmet in the presence of an 80-dB sound pressure level (SPL) white noise signal to assure maximum sound attenuation prior to obtaining test thresholds during each session.

All thresholds were obtained with a method of limits using alternative descending and ascending approaches to threshold. Subjects were given a response switch to indicate when the signals became inaudible or audible, as appropriate. Thresholds were calculated as the mean of the four intensities yielded by the descending and ascending trials at each frequency.

Sound field calibration was performed with a Bruel & Kjaer sound level meter (Type 2209), a microphone extension rod (Type UA 0196), a field microphone (Type 4145), and an octave filter set (Type 1613). The sound level meter was calibrated before and after each set of measurements with a pistonphone (Bruel & Kjaer, Type 4220). Intensity calibration at each test frequency was performed before and after each test day and was found to be within acceptable variation throughout the study. Attenuator linearity was measured in 10-dB steps before and after the study was performed. Attenuator dial changes of 10 dB resulted in sound pressure level changes of 10 $\pm$ 1 dB at all frequencies throughout the range used in this study.

The mean reference threshold sound pressure levels obtained for all subjects during each session of this study are shown in Figure 3 and

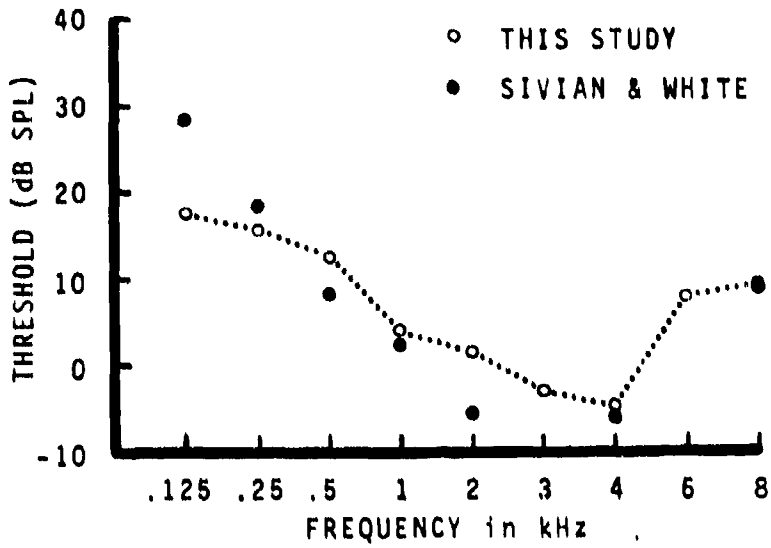


Figure 3. Mean sound field pure-tone thresholds obtained in this study. Sivian and White Minimum Audible Fields are shown for comparison.

Table 2. Also shown in Table 2 are the standard deviations of these measurements as well as the Minimum Audible Field sound pressure levels according to Sivian and White and listed in the ANSI Z24.22 standard. Table 2 shows that the mean reference thresholds obtained in this study did not exceed the Sivian and White Minimum Audible Field levels by more than 10 dB. Therefore, the test environment used for this study was considered to be adequate with respect to ambient noise levels according to specifications of the ANSI Z24.22 standard.

The reference threshold sound pressure levels were subtracted from the test threshold sound pressure levels for each subject at each test frequency for each test session to obtain the mean helmet attenuation data shown in Table 3. These data are given for the test helmet while using first the precast liner and then the custom-fit liners for each subject. Standard deviations of the measurements are shown. Statistical analysis revealed no significant differences at the .05 level between the mean helmet attenuation while using the precast liner or while using the custom-fit liners. Therefore, the means at each frequency were pooled to yield an overall mean helmet attenuation based on twenty subjects as shown in Table 4 and Figure 4, regardless of the type of liner used. For comparison purposes, Table 5 shows mean real-ear

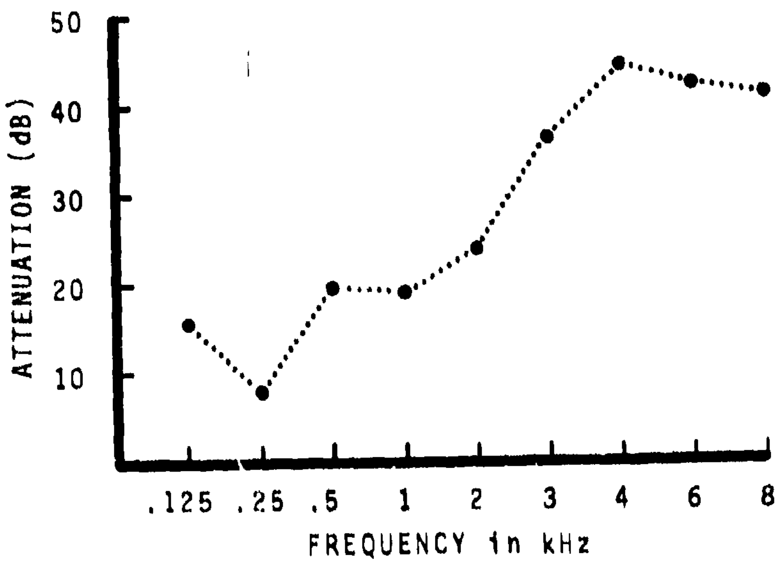


Figure 4. Mean real-ear attenuation of the Lightweight Helmet. Data points represent measurements obtained with the precast and the custom-fit liners (N = 20).

attenuation data obtained by Flugrath and Turbeville (1972) for six commonly available earmuffs. These data are approximate and have been interpolated from the published graphs. Also shown in Table 5 are the minimum real-ear attenuation values of the U.S. Army Aeromedical Research Laboratory for helmets worn by Army tank crewmen for comparison purposes. Foam insert combinations used with subjects in this study are shown in Table 6.

The noise attenuation studies conducted at the Redlands Medical Center allowed the following comparisons. When the LWH was compared with the DOD standard, which is not a helmet standard, it was found that the LWH attenuation characteristics were quite comparable to the current HGU-26/P. It should be noted that the LWH does not attenuate quite as well in the middle frequencies as does the HGU-26/P. After analysis by the Bioacoustics Branch of AMRL, it was their opinion that the LWH, with either the precast or the custom-fit liner, was adequate for its intended use in advanced tactical fighter aircraft. Therefore the Sierra LWH does not present a noise attenuation problem for its intended mission.

TABLE 2. SUBJECTS' MEAN REFERENCE THRESHOLD SOUND PRESSURE LEVELS

	.125	.25	.5	1	2	3	4	6	8	kHz
Mean reference thresholds obtained in this study	17.5	15.6	12.6	4.1	1.6	-2.9	-4.5	8.0	9.3	dB SPL
Standard deviations of reference thresholds obtained in this study	4.4	5.4	5.7	4.7	5.8	4.2	5.4	5.6	8.8	dB
Minimum Audible Field (Sivian & White)	28.5	16.5	8.5	2.5	-5.5		-6.0		9.0	dB SPL

TABLE 3. MEAN HELMET ATTENUATION DATA FOR PRECAST AND CUSTOM-FIT LINERS

	.125	.25	.5	1	2	3	4	6	8	kHz
a) Precast liner										
Mean helmet attenuation	15.5	7.3	19.9	19.6	24.3	36.5	43.7	42.3	40.5	dB
Standard deviation	2.5	1.5	3.9	4.3	1.9	3.7	5.5	8.8	9.4	dB
b) Custom-fit liner										
Mean helmet attenuation	15.6	8.2	17.3	18.2	23.4	36.7	45.5	43.1	41.6	dB
Standard deviation	1.6	2.4	4.0	6.0	2.1	3.3	4.6	6.5	9.6	dB

TABLE 4. OVERALL POOLED MEAN HELMET ATTENUATION FOR TWENTY SUBJECTS

	FREQUENCY									
	.125	.25	.5	1	2	3	4	6	8	kHz
Mean real-ear attenuation of the lightweight helmet, regardless of type of liner (N = 20)	15.6	7.8	19.6	18.9	23.8	36.6	44.6	42.7	41.2	dB

TABLE 5. COMPARISON OF MEAN NOISE ATTENUATION FROM OTHER STUDIES

	FREQUENCY									
	.125	.25	.5	1	2	3	4	6	8	kHz
Mean attenuation of 6 types of earplugs (Flugrath, 1972)	17.5	16.7	17.3	18.8	27.8		34.0		27.5	dB
Mean attenuation of 5 types of earmuffs (Flugrath, 1971)	12.6	15.9	23.6	28.1	29.8		31.1		26.9	dB
Minimum attenuation for U.S. Army tank helmets (Camp, 1974)	15.0	14.0	24.0	28.0	30.0	35.0	35.0		30/0	dB

TABLE 6. DETACHABLE FOAM INSERT COMBINATIONS USED WITH SUBJECTS

Subject No.	
1	one thin insert, both sides
2	no inserts
3	no inserts
4	one thin and one thick insert, both sides
5	one thin and one thick insert, both sides
6	no inserts
7	one thin and one thick insert, both sides
8	one thin and one thick insert, both sides
9	one thin and one thick insert, both sides
10	one thin and one thick insert, both sides

Windtunnel Test--The objective of this test program was to measure the aerodynamic loads and resulting moments acting on several helmet configurations exposed to sustained windblast in order to evaluate negative lift devices incorporated into the visor housing (see Glossary, p. 52, for aerodynamic nomenclature and symbols).

The Vought Corporation Systems Division Low Speed Wind Tunnel is a horizontal single-return, closed-circuit facility having tandem test sections of 4.6 m (15 ft) by 6.1 m (20 ft) and 2.1 m (7 ft) by 3 m (10 ft) dimensions. A 735-watt (1500 horsepower) electric motor provides power for the 6.1 m (20 ft) diameter, six-blade, fixed-pitch fan. The large test section may be operated at speeds up to 2.3 km (52 miles) per hour, and a maximum speed of 142.9 km (230 miles) per hour can be obtained in the small test section.

The test models used in this program consisted of various configurations of the Sierra Engineering Co. LWH and the HGU-26/P flight helmet (Fig. 2). All of the helmet configurations were attached to the head of an anthropometric dummy seated in a full size ACES-II ejection seat. The head of the dummy, which was not attached to the body, was mounted on the forward end of a strain gage balance.

The balance was supported by a sting protruding through a hole in the rear contour of the helmet; the sting was attached to a support frame on the back of the ejection seat. Mounted in this manner, the helmet and dummy head were isolated from the dummy body and ejection seat; therefore, only airloads acting on the helmet-head unit were measured by the balance. One of the helmet configurations ready for testing is shown in Figure 5.

The ejection seat was equipped with a pivot mounting mechanism which permitted the seat to be pitched forward and backward in 15-degree increments. The strut which supported the ejection seat was attached to the external balance below the test section floor. The external balance was used only as a means of supporting and yawing the model. Figures 6 and 7 show the ejection seat with the pitching mechanism and sting support frame.

Effects of the windblast loads acting on the dummy head and the attached helmet were measured with the VB-11 six-component strain gage balance designed to measure normal force, side force, axial force, pitching moment, yawing moment, and rolling moment. The balance is shown in Figures 8 and 9 mounted to the support sting which protrudes through the ejection seat headrest. Figure 10 shows the cylindrical adapter used to attach the balance to the dummy head. The blocks extending above and to the rear of the dummy head were used as attachment points to secure the helmet to the dummy head.

Figure 5. Test model mounted in test section.

Figure 6. Ejection seat.

On the 28th and 29th of July 1976, a test program was conducted in the Vought Corporation Systems Division Low Speed Wind Tunnel for Sierra Engineering Co. A total of 38 runs were made in the 2.1-m by 3-m (7- by 10-ft) test section at dynamic pressures varying from 0.7 to 2.7 ATA (10 to 40 psig). The purpose of the test was to determine the airloads on several flight helmet configurations exposed to sustained windload in order to evaluate the aerodynamic performance of the Sierra LWH.

All of the helmet configurations were attached to the same dummy head at the three mounting points. To prevent airflow between the inside surface of the helmet and the dummy skull, the gap between the helmet and skull was filled with sponge rubber held in place by gummed plastic tape.

At the beginning of the test program the ejection seat was mounted in the test section with the rails slanting rearward 12.5 degrees from the vertical. This orientation was defined as a = α 0°.

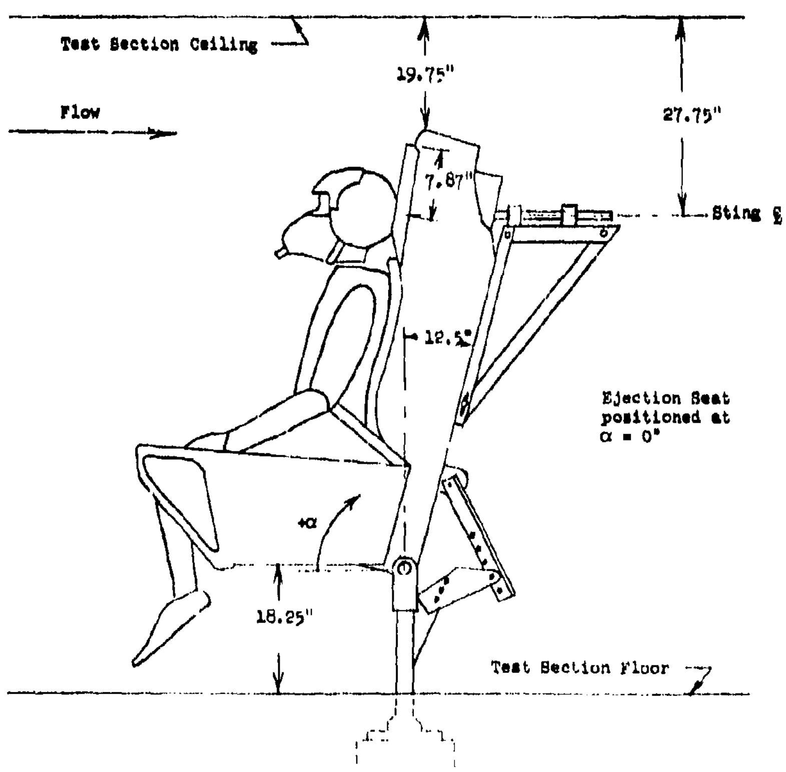


Figure 7. ACES-II ejection seat and dummy positioning.

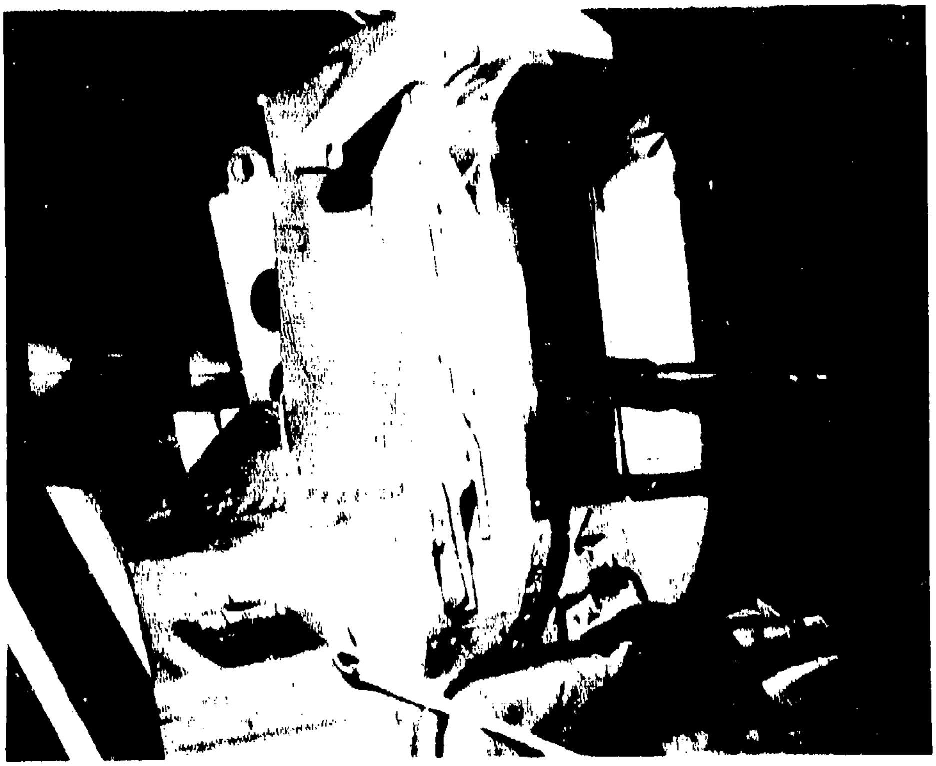


Figure 8. VB II balance on support sting.

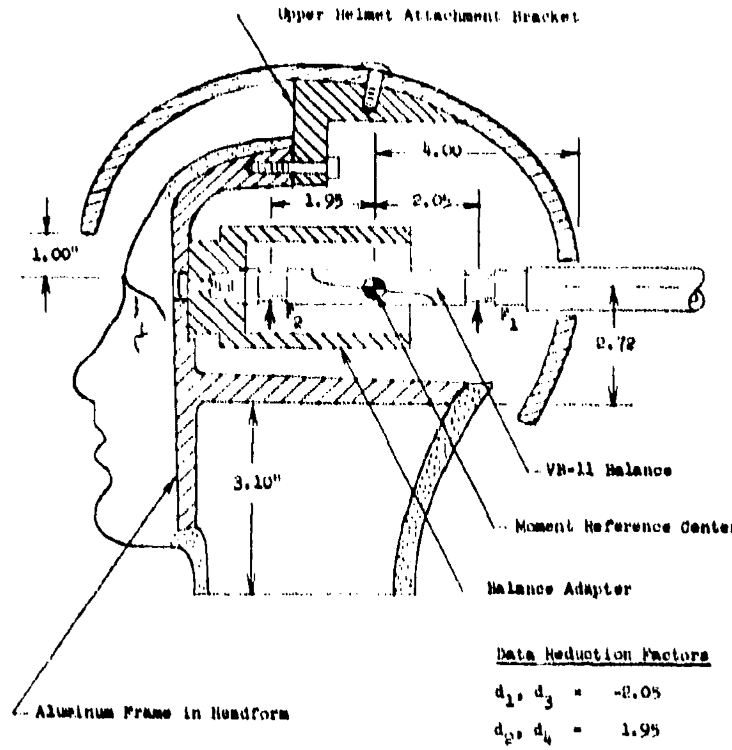


Figure 9. VB-11 balance in dummy headform.

With the ejection seat in this position, the VB-11 balance was mounted to the sting and support frame with the balance centerline in a horizontal plane (Fig. 11). The angular relationship between the balance centerline and the seat rails remained fixed throughout the test program. As the ejection seat was pitched forward and backward, the balance was pitched to the same angles.

The helmet-head test models were placed on the forward end of the balance and secured by a single cap screw inserted through a hole drilled in the bridge of the dummy's nose. The back of the helmet did not contact the seat headrest. The dummy body was positioned in the ejection seat and secured with flat binding straps to restrict movement of any portion of the body while the test was in progress. A small gap between the dummy body and head was maintained throughout the test program.

Figure 10. Dummy head mounted on VB-11 balance.

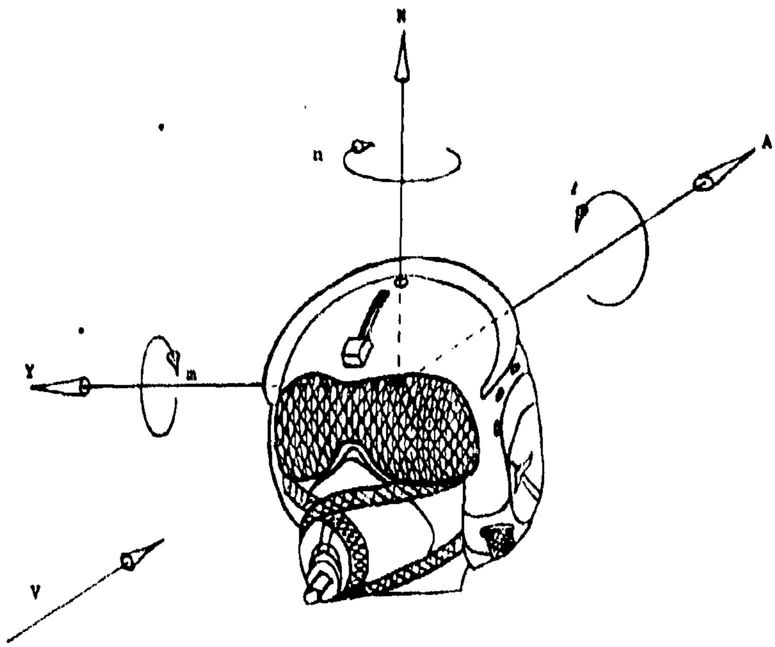


Figure 11. Axes system notation.

After the model had been prepared for a test run, the ejection seat was set at the required pitch angle and rotated to $\psi = 0^{\circ}$. The remainder of a test run consisted of rotating the ejection seat through the required yaw range, stopping at each data point to allow the flow to stabilize and to record the balance output. Final "wind-on" and "wind-off" data points were taken to verify correct operation of the system throughout the run.

Six component force and moment data (normal force, axial force, pitching moment, side force, rolling moment, and yawing moment) were recorded during each run as a function of model pitch angle and yaw angle. The data were resolved into a body axes system with forces computed along and perpendicular to the balance centerline and moments resolved about a point on the balance centerline 10.2 cm (4 in.) forward of the intersection of the sting centerline and rear contour of the helmet.

Two sets of data were computed, one in which the measured forces and moments were tabulated directly in pounds along the three axes and inch-pounds about the reference point. The other set of data was presented in coefficient form in which the forces were computed in terms of force area, having units of square feet, and the moments were computed in terms of moment volume, having units of cubic feet. The computation of the coefficients in this form was accomplished by using an existing data reduction routine which requires inputs of reference area in square inches and two reference lengths in inches.

The equations for the dimensionless coefficients are:

$$C_N = N/qS$$

$$C_A = A/qS$$

$$C_m = m/qSc$$

$$C_Y = Y/qS$$

$$C_\ell = \ell/qSb$$

$$C_n + n/qSb$$

where:

S = reference area
c = reference length
b = reference length

By substituting a unit reference area of 1 ft^2 (144 $in.^2/ft^2$) and a unit reference length of 1 ft (12 in./ft), the equations become:

$$C_N = \frac{N}{q(144/ft^2)} = \text{Normal Force Area} \sim ft^2$$

$$C_N = \frac{A}{q(144/ft^2)} = \text{Axial Force Area} \sim ft^2$$

$$C_m = \frac{m}{q(144/ft^2)(12/ft)} = \text{Pitching Moment Volume} \sim ft^3$$

$$C_Y = \frac{Y}{q(144/ft^2)} = \text{Side Force Area} \sim ft^2$$

$$C_\ell = \frac{\ell}{q(144/ft^2)(12/ft)} = \begin{array}{l}\text{Rolling Moment}\\ \text{Volume} \sim ft^3\end{array}$$

$$C_n = \frac{n}{q(144/ft^2)(12/ft)} = \begin{array}{l}\text{Yawing Moment}\\ \text{Volume} \sim ft^3\end{array}$$

The only corrections required for this program were the solid and wake blockage and compressibility corrections which were accounted for by operating the tunnel at a specific q_{set} value. This value was computed from the equation:

$$q_{set} = q \left(\frac{1}{5.20 \times q_u/q_{piez}}\right) \left(1 + \frac{M^2}{4}\right) \left(\frac{1}{1 + 2\epsilon_b}\right)$$

where:

q_{set} = piezometer ring differential pressure monitored by tunnel personnel while operating the tunnel at constant flow velocity, inches of water

q = desired test section dynamic pressure, pounds per square foot

q_u/q_{piez} = piezometer ring calibration factor (1.21)

$(1 + \frac{M^2}{4})$ = compressibility correction factor (M Mach number)

$(1 + 2\epsilon_b)$ = solid and wake blockage correction factor

$$\epsilon_b = \frac{1}{4} \; \frac{\text{Model Frontal Area}}{\text{Test Section Cross-Sectional Area}}$$

Data included the tabulated forces and moments and tabulated values of force area and moment volume. These data are presented in a balance axes system having its origin on the balance centerline at a point 10.2 cm (4 in.) forward of the intersection of the balance sting centerline and the rear contour of the LWH. Figures 12, 13, and 14 present an encapsulated view of the results.

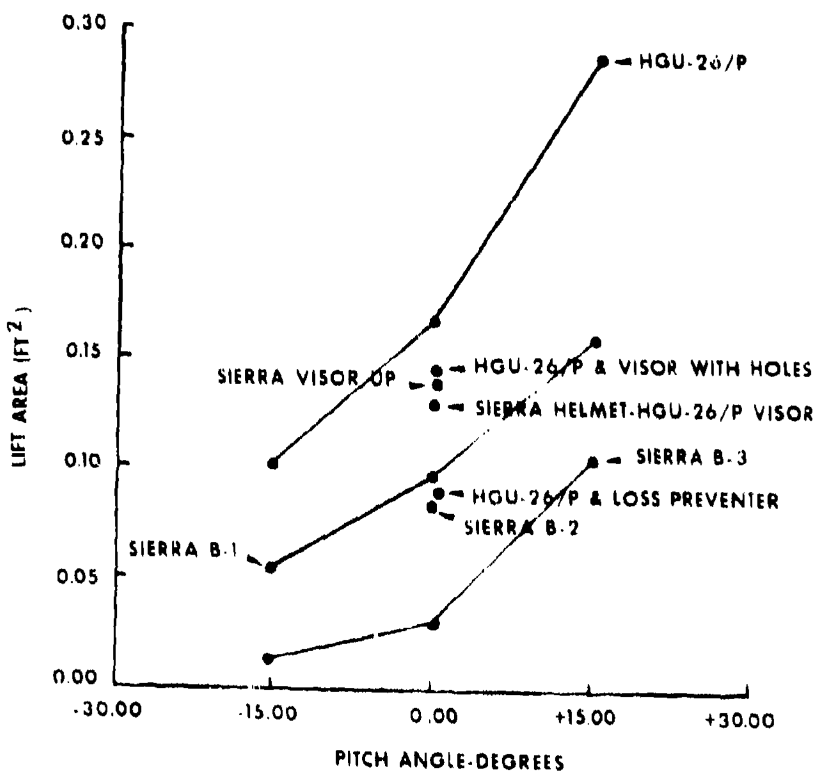


Figure 12. Lift vs. pitch.

Each of the configurations was compared with the HGU-26/P standard Air Force helmet which was tested under the same conditions on the same day. The results of the tests are seen in Table 7.

TABLE 7. WIND TUNNEL TEST: LIFT REDUCTION AT ZERO PITCH, ZERO YAW

Configuration	Reduction
HGU-26/P	
Sierra (Louvers and Crescent)	42%
Sierra (Vented Louvers)	47%
Sierra (Antilift Loop)	78%

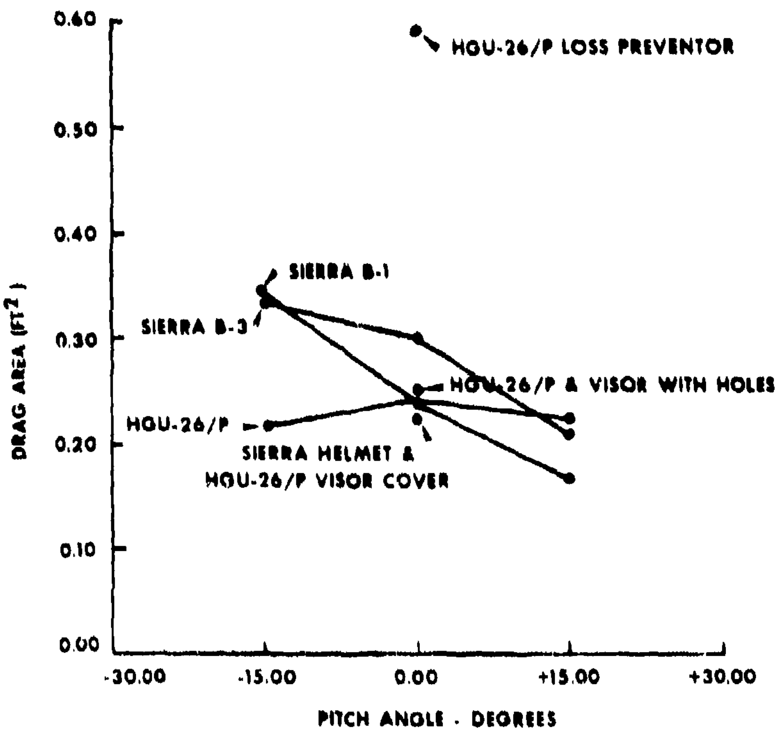


Figure 13. Drag vs. pitch.

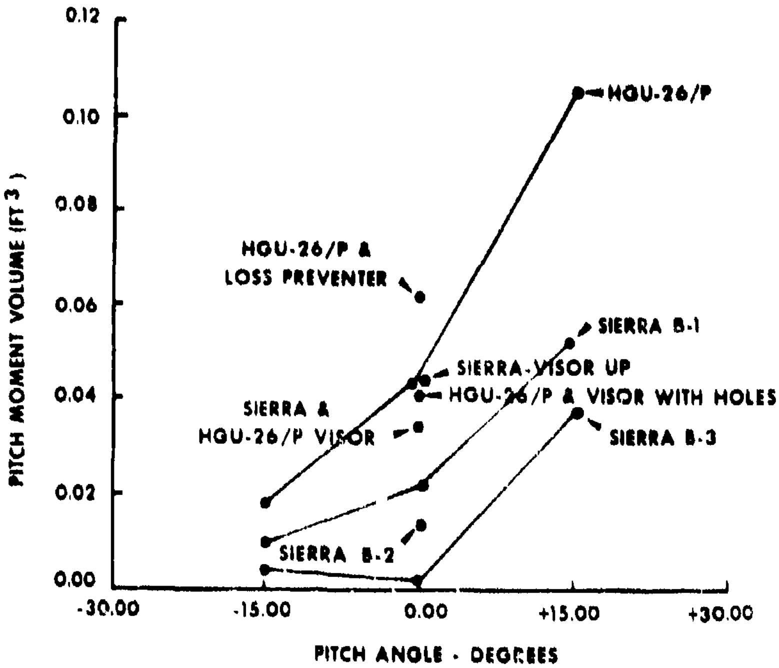


Figure 14. Pitch moment volume vs. pitch.

Although the louvered visor housing was ultimately chosen for Phase II, the 78% reduction afforded by the Sierra antilift loop is the most dramatic, especially if the figure is translated into pounds of lift force. Whereas the current HGU-26/P generates 270 pounds of lift force at approximately 450 knots, the Sierra antilift configuration generates only 59 pounds of lift under the same conditions.

Impact/Penetration Test--Sierra Engineering Co. maintains a helmet test facility capable of meeting the requirements of ANSI Z90.1 1971/ Z90.1A 1973 impact and MIL-H-83147 penetration tests. The impact test was modified by the Air Force to include:

1 impact per site - 4 sites

Size C test headform

No thermal preconditioning allowed

The following results apply for individual helmets:

Test date: 8/25/76
Lab request No.: 60475 Size: Large

IMPACT LOCATION	PEAK ACCELERATION (g)
APEX	104.8
FRONT	159.3
REAR	221.8
RIGHT	135.1
LEFT	123.0

Penetration results: Acceptable at all 7 locations.

Test date: 9/7/76
Lab request No.: 60508 Size: Medium

IMPACT LOCATION	PEAK ACCELERATION (g)
FRONT	197.6
REAR	160.3
RIGHT	121.0
LEFT	132.1

Penetration results: Acceptable at all locations.

Test date: 9/10/76
Lab request No.: 60513 Size: Large

IMPACT LOCATION	PEAK ACCELERATION (g)
FRONT	135.1
REAR	110.0
RIGHT	116.9
LEFT	122.0

Penetration results: Acceptable at all locations.

Test date: 10/12/76 Size: 1st medium
Lab request No.: 60576 2nd medium

IMPACT LOCATION	PEAK ACCELERATION (g)
First Helmet:	
FRONT	195.6
REAR	328.6
RIGHT	132.1
LEFT	132.1
Second Helmet:	
FRONT	350 plus
REAR	253.0
RIGHT	202.6
LEFT	196.6

Penetration results: Acceptable at all locations on both helmets.

The Impact/Penetration tests on five helmets revealed that the LWH met or exceeded the Air Force specifications. The helmets withstood 60 ft-lb of impact without failing and successfully passed the penetration tests. It should be noted that the 60 ft-lb was the total impact energy and included the helmet weight. These shells used the epoxy resin system employed in the Phase II flight test helmets.

Fit--All fitting tests were conducted at ground level. The following areas were evaluated: (1) helmet weight; (2) visor/spectacle compatibility; (3) visor/mask integration; (4) helmet/mask integration; (5) ease of donning and doffing; (6) ease of operation of the visor control knob with gloved hand; (7) comparison of two LWH liners relevant to fit.

(1) The mean helmet weight was 1.06 kg (2.39 lb).

(2) Visor/spectacle interference was noted in two of six subjects wearing the LWH with the MBU-5/P and MBU-12/P oxygen masks.

(3) Visor/offset bayonet interference was noted in three of six subjects wearing the LWH with the MBU-5/P and MBU-12/P oxygen masks.

(4) Only two out of six subjects could be fitted in the medium LWH and MBU-12/P (insufficient adjustment in mask straps using standard and offset bayonets caused this problem).

(5) Full adjustment using standard bayonets was not attained.

(6) The subjects found the operation of the visor control knob comparable to the HGU-26/P. Only one subject felt the LWH control knob was easier to use.

(7) All subjects preferred the custom-fit liner. Most subjects found that the precast liner did not press uniformly over the top of head. (See Table 8 for anthropometric details.)

Maintainability--Ease of disassembly/reassembly of the LWH components was evaluated by life support technicians.

(1) Visor change and chin and nape strap replacement were less difficult than HGU-26/P.

(2) Communications system was much less difficult than HGU-26/P.

(3) Changing bayonet receivers and cleaning the LWH was similar to the HGU-26/P.

Retention/Pressure Breathing--After ensuring that the helmet/mask was fitted to maintain 4 mm Hg safety pressure without leak, mask pressures were incrementally increased from 0 to 10, 20, 30 mm Hg to establish retention characteristics of the helmet/mask combination. Several combinations were necessary for comparative purposes.

Only slight differences were noted in retention/pressure breathing characteristics in all helmet/mask combinations, except the medium-size LWH and MBU-12/P where fit and adjustment problems were encountered. The LWH and MBU-5/P held similar mask pressures as the HGU-26/P - MBU-5/P at the 10, 20, and 30 mm Hg levels.

Fixed Visual Fields--Using the same equipment combinations, visual fields were measured and plotted with a Goldman projection perimetry device. Peripheral fields were slightly greater using the LWH and MBU-5/P oxygen mask as compared to the HGU-26/P helmet. This feature, together with the increase in downward vision using the MBU-12/P mask, increases crewmember visibility over the standard equipment standardly worn. The visual field plots are shown in Figures 15 through 18.

Altitude Testing--Prior to manned runs, both helmet liners were decompressed to 13,106 m (43,000 ft) to ensure that the degree of gas expansion in the liners would not pose problems during altitude runs. The altitude profile was used to demonstrate the dynamic response of the earcup and liner to pressure change. Human subjects were then exposed to a similar flight profile. Subjects made an ascent to 2,439 m (8,000 ft) where they were rapidly decompressed to 7,012 m (23,000 ft) in 2-3 seconds followed by a descent to ground level at 25.4 m/s (5,000 ft/minute). During these tests one subject wore a medium-size LWH with a custom-fit head liner (LWH-1) with MBU-5/P mask. No recognizable problems were associated either on the ascent to 13,106 m (43,000 ft) or during the rapid decompression. There was no indication that foam size increased at lower pressures or that any "earcup bounce" occurred. The liners were decompressed unmanned to 13,106 m (43,000 ft) without significant change in size.

Thermal Test--The six subjects were exposed to a T dry bulb temperature of 35°C (95°F), R.H. 50%, and T black globe temperature of 47°C (117°F). They were exposed to these temperatures for approximately 40-60 minutes to determine head temperature equilibration times and level of thermal comfort in sunlight cockpit conditions. All wore MBU-5/P oxygen masks during the thermal evaluation. The same six subjects were tested in each of three helmet configurations, viz., HGU-26/P, medium-size LWH, and the large-size LWH wearing the MBU-5/P mask. There was no meaningful difference among helmets (Table 9). Comparison of results of LWHs that were painted blue vs. white showed no significant differences.

Acceleration Test--Using the same equipment combinations, five subjects were exposed to the following G levels while wearing anti-G suits: (1) 3 G/15 seconds, (2) 4.5 G/10 seconds, and (3) 7 G ACM profile.

The subjects' faces were marked with a black grease pencil at 1.27-cm (1/2-inch) intervals, and video tapes were used to assess mask/helmet movement. No meaningful differences were noted in helmet stability/mask retention characteristic in all helmet combinations except the medium-size LWH and MBU-12/P where fit and adjustment problems were encountered. In most cases the MBU-5/P did move down on the face approximately 1.27-cm (1/2 inch). It should be remembered that the masks were fitted to maintain a 4 mm Hg safety pressure without leak; i.e., a tighter fit would have maintained position of the mask at the 7 G level, but would have been relatively uncomfortable over long periods of time.

Voice Communications Effectiveness--These tests were conducted at the 6570th Aerospace Medical Research Laboratory at Wright-Patterson AFB, Ohio. The evaluation consisted of laboratory measurements of talker and listener speech intelligibility in simulated cockpit noises of the F-15 and F-16 high-performance aircraft. Data showed that communications performance with the helmet systems in the F-15 and F-16 cockpit noise environments was virtually the same using the Modified Rhyme Test. The communications effectiveness of either configuration of the Sierra helmet was found to be equivalent to the current standard HGU-26/P with custom liner and H-154 (A) earcups. (See Table 10.)

TABLE 8. ANTHROPOMETRIC DETAILS OF SUBJECTS

Cm/Percentile

Subject No.	Helmet Size HGU-26/P	Helmet Size LWH	Mask Size MBU-5/P	Mask Size MBU-12/P	Head Length	Head Breadth	Bizygomatic BR	Bigonial BR
1	Large	Large	Reg narrow	Reg	19.9/53.0	15.6/50.0	12.9/<1.0	10.0/<1.0
2	Large	Medium	Reg narrow	Reg	19.6/35.0	14.8/7.0	14.0/35	10.3/2
3	Large	Large	Reg narrow	Reg	20.4/80	14.8/7.0	13.6/10	10.25/2
4	Large	Large	Reg narrow	Reg	20.1/65	15.3/30	14.0/35	11.2/23
5	Large	Medium	Reg narrow	Reg	19.6/35	15.7/55	14.2/50	11.0/15
6	Large	Large	Reg narrow	Short	20.4/80	14.2/25	13.8/20	11.0/15

Subject No.	Max Frontal BR	Menton Crinion Lgth	Menton Nasal Root Lgth	Length Lip	Head Circ	Min Frontal Arc	Bit Subnasal Arc	Bit Menton Arc	Bit Submandibs Arc
1	10.2/<1	17.7/14.0	11.9/14.0	4.8/12.0	57.7/55.0	11.9/1.0	28.4/20.0	32.0/30.0	30.3/33.0
2	10.9/5	18.1/25	11.9/40	5.0/30	56.8/33	12.7/13	29.5/55	32.3/40	31.8/70
3	11.2/15	19.2/70	12.0/50	5.4/70	58.6/77	12.8/15	28.0/10	32.0/30	29.5/17
4	11.3/25	18.8/55	11.4/15	5.1/38	57.4/47	12.7/13	29.2/50	32.4/43	28.8/9
5	10.9/5	18.6/45	12.2/60	5.6/85	57.4/47	13.7/51	29.0/38	32.6/50	30.2/32
6	10.4/3.5	18.0/23	11.1/7	4.9/20	57.9/60	12.4/7	28.5/27	31.0/9	28.2/4

TABLE 9. RESULTS OF THERMAL TESTS OF LIGHTWEIGHT AND STANDARD HELMETS

Data at t=60. Chamber conditions: $T_{db} = 35^{o}C$, $T_{bg} = 47^{o}C$, and R.H. = 50%. N = 6 throughout.

		Temperatures (°C)		
		Forehead	Vertex	Occiput
Ltwt #1 (custom-fit liner)	Mean	35.9	37.6	36.7
	SD	0.8	0.4	0.3
Ltwt #2 (precast liner)	Mean	35.6	37.6	36.4
	SD	0.5	0.6	0.3
Std 26/P	Mean	35.1	37.8	36.3
	SD	0.6	0.4	0.7

TABLE 10. COMMUNICATIONS EFFECTIVENESS OF SELECTED HELMET SYSTEMS

	Simulated Cockpit Noise	
Helmet System	F-15 Aircraft	F-16 Aircraft
HGU-26/P with custom liner	83.6	83.3
Sierra lightweight helmet with the precast liner	83.4	83.0
Sierra lightweight helmet with the custom liner	82.6	83.0

*Levels of simulated noise spectra

Aircraft	A-Weighted Level	OASPL
F-15	110 dB	115 dB
F-16	106 dB	106 dB

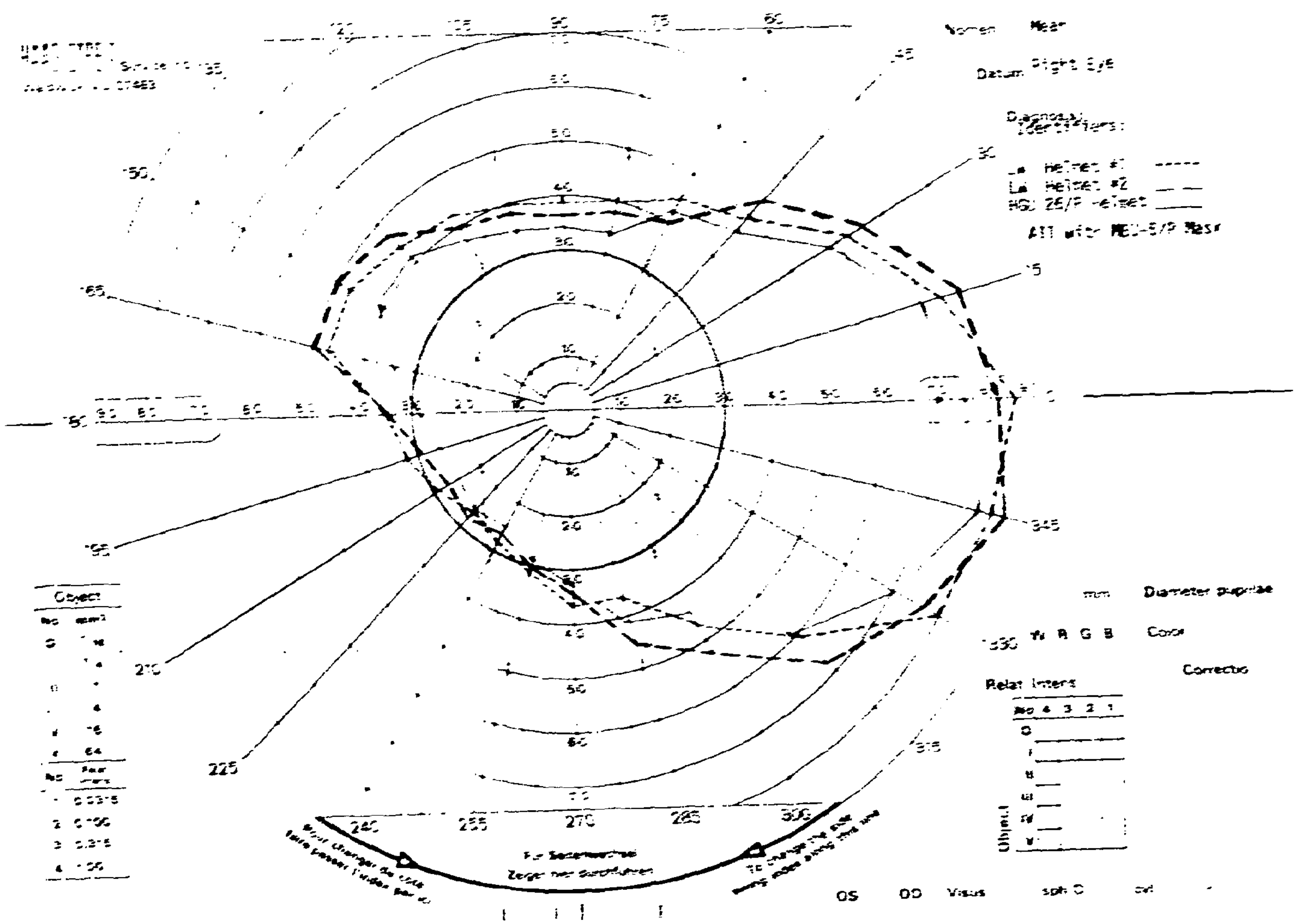


Figure 15. LW helmet #1 & #2 and HGU 26/P helmet--all with MBU-5/P mask (right eye).

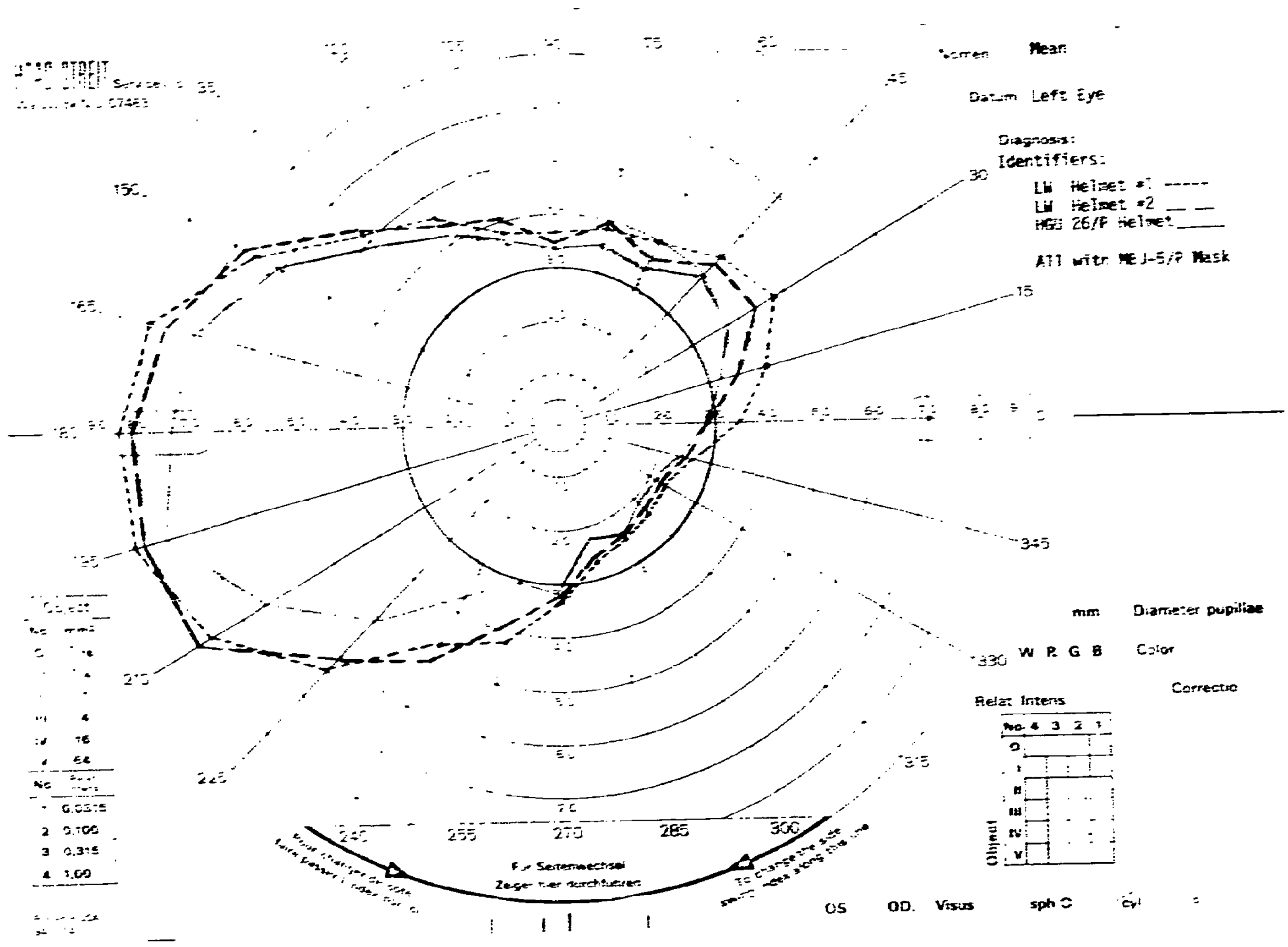


Figure 16. LW helmet #1 & #2 and HGU 26/P helmet--all with MBU-5/P mask (left eye).

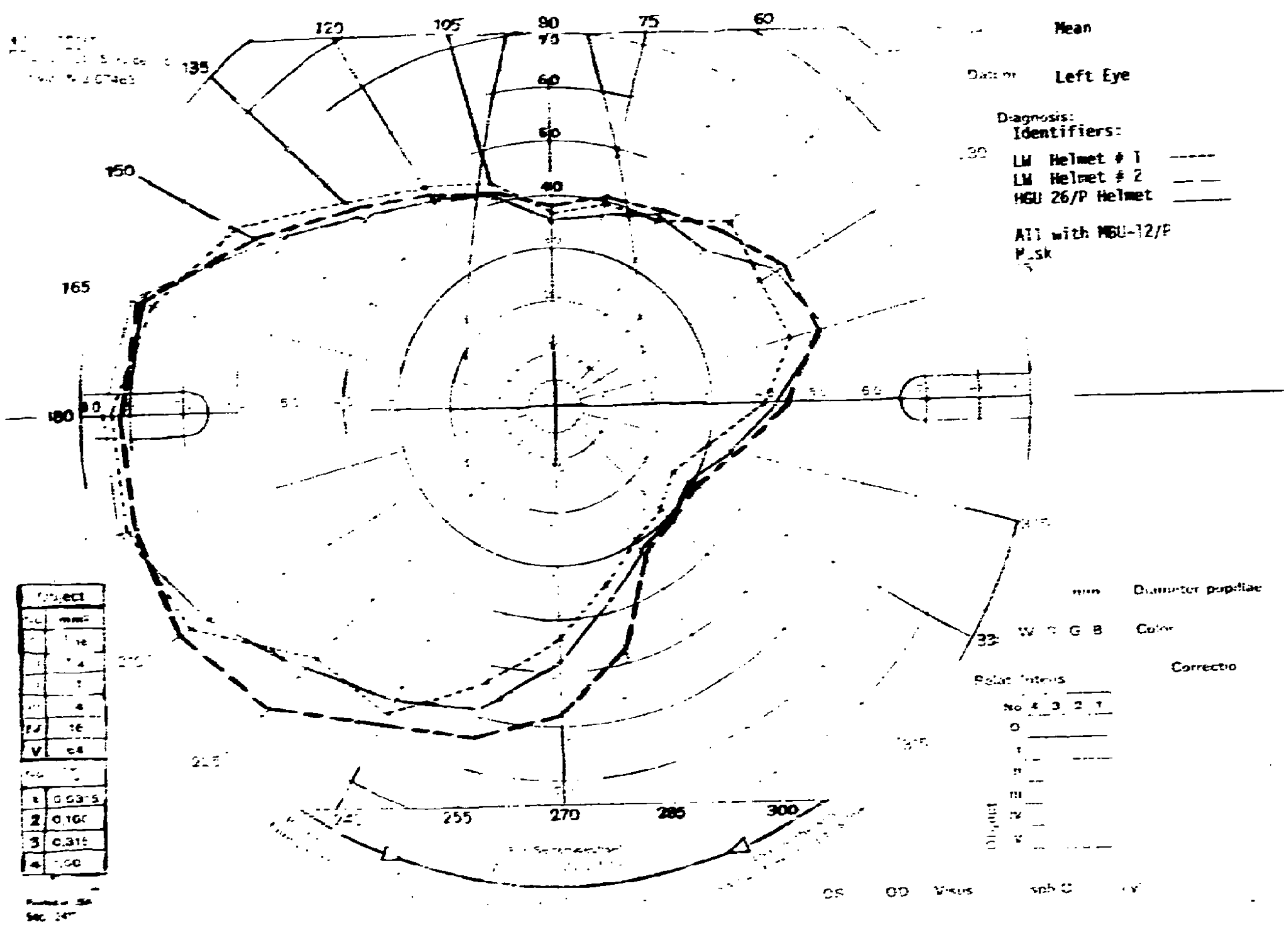


Figure 17. LW helmet #1 and #2 and HGU 26/P helmet--all with MBU-12/P mask (left eye).

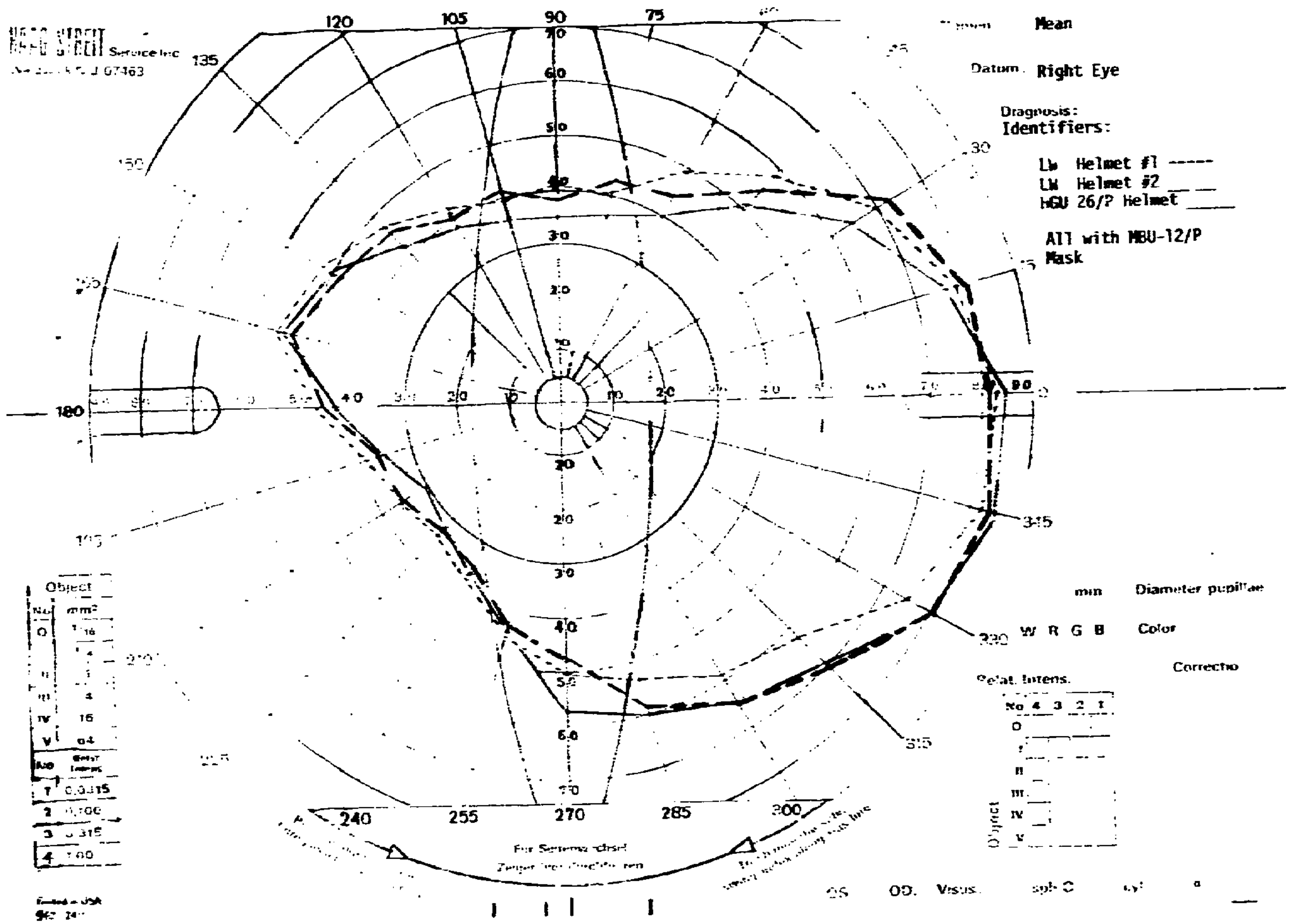


Figure 18. LW helmet #1 & #2 and HGU 26/P helmet--all with MBU-12/P mask (right eye).

Chemical Defense Equipment Compatibility--Leak studies were conducted using a sodium chloride (NaCl) cloud around the subjects' upper torso and sampling continuously at 1 l/min from within the visor compartment of the full-face firefighters' mask (FFFM). The two helmet combinations, viz., HGU-26/P and medium-size LWH-1, were worn on top of the elastic head harness of the FFFM. NaCl leaks were detected by a highly sensitive flame photometric system.

Only the custom-fit HGU-26/P and the medium-size LWH were comparatively tested. There was no meaningful difference between the two helmets, although there was a trend toward less leakage in the LWH with the FFFM than with the HGU-26/P. Both custom-fit helmets were uncomfortable while wearing the FFFM. (See Table 11.)

Cockpit Compatibility Assessment--Limited cockpit evaluations were conducted by having pilots, wearing normal flight gear and parachutes, enter the cockpits of the F-5 and F-15 aircraft, while comparing the function of both the HGU-26/P and LWH at different seat heights and with canopy up and down.

An F-5 pilot and F-15 pilot made the following comments during this limited assessment:

1. LWH was significantly lighter and more comfortable than HGU-26/P.

2. Peripheral vision and head mobility were both better.

3. They noted that the standard AF spectacles could be used with the LWH.

Subjective/Observer Evaluation--Comfort of the helmet was subjectively assessed using a modified pilot's evaluation form for a Navy lightweight helmet. Only those questions applicable to the USAF evaluation were used. In general the LWH was found to be very comfortable and could be rated above the HGU-26/P in all categories, except for the helmet/MBU-12/P mask integration problem and the visor/spectacle interference noted above. The shortened version of the chin strap pad was not well liked since it apparently does not distribute the weight evenly under the chin.

Windblast--One each Sierra helmet and one each HGU-40/P helmet were subjected to windblast tests at the Aeronautical Systems Division (ASD), Wright-Patterson AFB, Ohio, on 8 September 1976. Test parameters were as follows:

Position - Frontal

Peak Velocity - 450 knots

Rise Time - 0.3 seconds

Decay - 9 seconds to 180 knots

The helmet remained in place on the test headform without damage to the helmet assembly or components. Lifting forces on the helmet appeared to be exceptionally low as evidenced by mask/visor separation less than 0.64 cm (1/4 in.) during peak velocity.

Phase 1 Design Modification

At the end of Phase the following recommendations were made by the Air Force for improvements or modifications to the LWH.

Mean helmet weight was found to be approaching the proposed maximum weight of 1.1 kg (2.5 lb) and likely would exceed the target in an extra-large-size LWH. It was requested that efforts be made by the contractor to reduce weight by making cutouts in the louvers. It was thought that removing the crescent spoiler would result in greater user acceptance and reduce the weight further.

Visor/spectacle interference was limited to two subjects. Slightly increasing the pad dimensions over the forehead thereby moving the wearer further back into the helmet was suggested as a possible solution. Care must be taken to prevent a decrease in peripheral vision.

The offset bayonet interacted with visor closing in the LWH. USAFSAM recommended either using the straight or short bayonets or bringing the wing of the offset in closer to the edge of the helmet. An immediate problem was noted in mating the LWH and MBU-12/P mask using offset bayonets. Aircrews have been impressed with the comfort and increased downward vision afforded by the MBU-12/P. Therefore, further integration efforts to mate these two components were considered highly desirable.

The visor control knob was easy to operate, but a screw adjustment hole in the rubber cover should be enlarged and the rubber knob cover permanently affixed with a high-quality adhesive.

The custom-fit helmet liner was preferred and recommended for the flight trials.

Maintainability (USAF Recommendation)--Some receiver slippage was noted during the centrifuge test and should be prevented in future helmets.

It appeared that the "gull" shape of the browline could be trimmed back to coincide with the visor housing. This will increase peripheral vision even more than at present.

Rise Time - 0.3 seconds

Decay - 9 seconds to 180 knots

The helmet remained in place on the test headform without damage to the helmet assembly or components. Lifting forces on the helmet appeared to be exceptionally low as evidenced by mask/visor separation less than 0.64 cm (1/4 in.) during peak velocity.

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Mean helmet weight was found to be approaching the proposed maximum weight of 1.1 kg (2.5 lbs) and likely would exceed the target in an extra-large-size LWH. It was requested that efforts be made by the contractor to reduce weight by making cutouts in the louvers. It was thought that removing the crescent spoiler would result in greater user acceptance and reduce the weight further.

Visor/spectacle interference was limited to two subjects. Slightly increasing the pad dimensions over the forehead thereby moving the wearer further back into the helmet was suggested as a possible solution. Care must be taken to prevent a decrease in peripheral vision.

The offset bayonet interacted with visor closing in the LWH. USAFSAM recommended either using the straight or short bayonets or bringing the wing of the offset in closer to the edge of the helmet. An immediate problem was noted in mating the LWH and MBU-12/P mask using offset bayonets. Aircrews have been impressed with the comfort and increased downward vision afforded by the MBU-12/P. Therefore, further integration efforts to mate these two components were considered highly desirable.

The visor control knob was easy to operate, but a screw adjustment hole in the rubber cover should be enlarged and the rubber knob cover permanently affixed with a high-quality adhesive.

The custom-fit helmet liner was preferred and recommended for the flight trials.

Maintainability (USAF Recommendation)--Some receiver slippage was noted during the centrifuge test and should be prevented in future helmets.

It appeared that the "gull" shape of the browline could be trimmed back to coincide with the visor housing. This will increase peripheral vision even more than at present.

TABLE 11. SODIUM CHLORIDE CLOUD TEST WITH FULL-FACE FIREFIGHTERS MASK (ELASTIC STRAPS) AND HELMET COMBINATION

(6 Subjects)

Protection Factor	BASE		DPBR		UPDN		SIDE		FACL		VALS	
	HGU-26/P	LWH-1	HGU-26/P	LWH-1	HGU-26/P	LWH-1	HGU-26/P	LWH-1	HGU-26/P	LWH-1	HGU-26/P	LWH-1
Mean	3405	5057	3420	5349	3593	3785	3404	2199	3394	3642	8333	7917
S.E.	2085	2210	2080	2214	2035	2003	2086	1592	2089	2019	1054	1357

Legend:

BASE - Quiet breathing

DPBR - Deep breathing

UPDN - Up and down head movements

SIDE - Side to side head movements

FACL - Facial movements

VALS - Valsalva maneuver, i.e., safety pressure and fingers under face seal

Aircrew in the F-5 are especially interested in a very low profile helmet. To maintain a high degree of visibility over the nose of the aircraft, they prefer to sit with their heads 3-5 cm from the canopy. The raised spoiler portion of one helmet configuration presents an additional point for the pilot's helmet to strike the canopy. Considering pilot comments and the fact that the louvered visor cover decreases lift to a greater degree than the standard HGU-26/P, USAFSAM recommended that the louvered visor housing be used for upcoming flight trials in the AIMVAL/ACEVAL program, i.e., remove crescent spoiler from visor housing.

Other Modification Problems--The short end of the chinstrap was found to be difficult to locate because it emerges from the inside of the helmet as a continuous loop from the nape. It was requested that this strap be made easier to locate.

The following are the contractor's comments/action relevant to the USAF recommendations.

No appreciable weight reduction was possible by removing the spoiler or making the cutouts. The source of further potential weight reduction in the LWH is the aramid shell. Much filler material was used underneath the exterior paint in order to achieve a smooth finish. It was felt that this could be overcome in production by use of a specially shaped molding bag.

Four additional subjects were tested for visor/spectacle interference. No interference was noted in any of these subjects. It was felt that the LWH was identical to the HGU-26/P in this regard.

Short bayonets were provided for use in Phase II. In addition, the shell trimline was taken-in just in front of the bayonet receivers in order to facilitate more complete insertion of the bayonets.

Some experimental work was done using the receivers located on the flat helmet sides in conjunction with the offset bayonet. Sierra felt this configuration might have advantages over previous locations, but was beyond the scope of the effort because of the time element.

The screw adjustment hole was enlarged and the knob cover was bonded with Dow Corning A-4000 adhesive.

The custom-fit liner was used exclusively in Phase II.

A friction-type lock washer was put under the receiver. It was also requested that external adjustment of the receiver be incorporated to allow easier fitting and adjustment. This was accomplished by inserting the mounting screws from outside the helmet rather than inside.

The recommended improvement in the LWH and MBU-12/P mask fitting interface would resolve any problems in this area.

The browline "gull" shape was decreased slightly.

The recommended improvement in the LWH and MBU-12/P mask fitting interface would most likely resolve any problems with mask slippage under G.

The louvered visor cover was used in Phase II.

The LWH was modified so the short end of the chinstrap emerged from the outside of the helmet, in the same position as the chinstrap on the HGU-26/P. This was done by the addition of an extra slot in the side of the helmet. This solution had the advantage of providing additional adjustment when tightening the chinstrap. A disadvantage was that the friction of the strap being woven through one extra slot in the side of the helmet caused some lessening of the Chinese Finger Cuff retention effect.

By the end of Phase I the aramid shell had developed a history of being resin rich in the exterior areas immediately below the flat ear sections. Although it was felt that this presented no major problem in a production mold, the difficulty had been enhanced by the use of the polyester resin system. In some cases, air trapped in the mold by the sharp contour caused large bubbles in these areas. These bubbles were below the protection area and were repaired with epoxy patch mix. The previously used epoxy resin was more flowable and reduced this problem. During trim and drill operations on the Kevlar, it was observed that the polyester resin shells were much more difficult to machine. Delaminations at drill holes, fuzzing of trimlines, and generally inferior machinability characteristics were experienced.

Because of these difficulties and because of more difficult surface preparation for painting, it was then decided to return to an epoxy resin system. The epoxy resin shell was used in all further impact and penetration studies and in Phase II. The epoxy shell was fabricated from 4 layers of Kevlar cloth. The purpose of the fiberglass was to reduce the amount of priming material that would otherwise be required prior to painting. Four of these shells were tested and passed ANSI Z90 modified impact requirements and MIL-H-83147 penetration requirements.

FLIGHT TESTING (PHASE II)

Test Requirements

On 13 October 1976, a Safety Analysis Review Meeting was held at Nellis AFB, Nevada for the Sierra LWH and two other lightweight helmets. Full safety clearance was given the Sierra LWH for purposes of DT&E/OT&E testing in the AIMVAL/ACEVAL program.

In October 1976, Sierra Engineering Co. delivered 20 LWH units to Nellis AFB for Phase II evaluation during the AIMVAL/ACEVAL program. Testing of the helmets was conducted in accordance with the Comparative Lightweight Helmet Evaluation (CDIOT&E), ASD Project ASD-TR-76-25, and TAC Project 76CT 083T. Twenty crewmembers participating in AIMVAL/ACEVAL wore each helmet on 16 consecutive flights and then completed a narrative questionnaire noting deficiencies and advantages of each helmet as it affected their ability to perform the F-5 and F-15 mission requirements. After each crewmember had completed the first 16 flights with the helmet, he began wearing the Sierra LWH alternately with two other candidate lightweight helmets. Then he completed a questionnaire which compared the relative value of each helmet as it applied to head mobility in terms of canopy clearance and headrest compatibility; comfort in terms of weight and center of gravity, fit, heat load, and stability; communications effectiveness in terms of noise attenuation, speech intelligibility, and output; and functionality in terms of visor operation, field of view, oxygen mask integration, oxygen mask function, ease of donning and doffing, and component integration. Aircrewmembers used their standard helmet as the baseline for judging the relative value of the helmets. Average mission duration was 0.8 hours. Maximum sustained acceleration on each flight ranged from 5 to 7 G.

Furthermore, maintenance support technicians were asked to determine the effectiveness of the helmets in the areas of reliability, durability, and the amount of required logistic support.

The 20 helmets delivered in Phase II were custom-fitted to the AF designated crewmen participating in the AIMVAL/ACEVAL program. The helmets were painted grey to minimize canopy reflections.

Test Results

Analysis of the completed questionnaires showed the following:

1. The visibility, stability, freedom of head movement, and overall component integration were slightly better than with the standard helmet.

2. A majority of the aircrewmembers did not receive a satisfactory liner fit. Three attempts were made to correct the fitting problems, but none satisfactorily solved the problems. The poor fit degraded both comfort and acoustic attenuation.

3. The integrated nape and chin strap was difficult to snap and caused a choking effect when the aircrewmember rotated his head upward. A reduction in the width of the nape pad reduced this problem but did not eliminate it.

4. The miniature bayonets did not provide sufficient adjustment capability. Standard bayonets were installed on the helmets of aircrewmembers who experienced adjustment problems. The use of standard bayonets resolved the adjustment problems.

5. The helmet was stable during high G maneuvering.

The unsatisfactory fit of most of the custom liners is believed to be the result of a random minor distortion in the 20 helmet shells fabricated for this test. As of the date of this report, no correction for this difficulty has been achieved.

CONCLUSION AND RECOMMENDATIONS

Although it was felt that the Sierra LWH incorporated many desirable features, the test program highlighted the importance of comfort in acceptance of personal flight equipment. The uncomfortable liner experienced by most of the Phase II users compromised the acceptance of the helmet. The only other significant detraction from the LWH was the retention strap system; the helmet wearer felt that the standard strap system was more comfortable even though better retention was provided by the continuous loop system. Other than reduced weight, the most significant advantages of the Sierra LWH were felt to be safety oriented such as the lift-reducing visor housing and/or the minimizing of protrusions or edges on which a parachute shroud line can catch. The reduced width and soft elastomeric earcups were also considered to be advantageous.

A significant improvement over the standard helmet can easily be achieved by elimination of the negative characteristics mentioned above. A very limited number of improved versions of this helmet could be fabricated and compared by aircrew personnel with an equal number of the remainder of the original version of this helmet. Specifically, the improved version will not induce liner distortion and would have a standard retention strap system using lightweight pads and buckle.

It is recommended that the fabrication of the USAF custom-fit liner be further developed as a pour-in-place operation for this helmet. This would eliminate the "Iron Maiden" molding gear currently used without adding to the weight of the finished liner.

BIBLIOGRAPHY

American National Standards Institute. Method for the measurement of the real-ear attenuation of ear protectors at threshold. ANSI Z24.22, 1957.

American National Standards Institute. Criteria for background noise in audiometer rooms. ANSI S3.1, 1960.

American National Standards Institute. Specifications for audiometers. ANSI S3.6, 1969.

American National Standards Institute. Specification for protective headgear for vehicular users. ANSI Z90.1-1971/Z90.1A-1973.

Billings, B. L. Real ear attenuation study: Super high-G aircraft flight helmet. Audiology Center of Redlands Medical Clinic, Inc., Aug 1976.

Camp, R. T., et al. Letter Report USAARL LR 75-18-2-8, Nov 1974. (Makes reference to Minimum Acceptable Attenuation Values for U.S. Army Tank Helmets (page 1).)

Flugrath, J. M., and J. B. Turbeville, Jr. The effectiveness of earplugs. Sound and Vibration, May 1972.

Flugrath, J. M., and B. N. Wolfe. The effectiveness of selected earmuff-type hearing protectors. Sound and Vibration, May 1971.

Lindsey, J. L. Vought Corporation. Report LSWT 513, Determination of windblast forces and moments on the Sierra Engineering Co. super high-G helmet, 29 Nov 1976.

Military Specification. Helmet shell, flying, HGU-22/P. MIL-H-83147 USAF, 24 June 1968.

North Atlantic Treaty Organization. AGARD Conference Proceedings No. 170, Biodynamic response to windblast, July 1975.

Sierra Engineering Co. Technical Proposal No. 570-942, Super High-G Helmet, March 19, 1976.

USAF School of Aerospace Medicine. Preliminary Report, USAF evaluation of the Sierra Lightweight Helmet, 1977.

BIBLIOGRAPHY

American National Standards Institute. Method for the measurement of the real-ear attenuation of ear protectors at threshold. ANSI Z24.22, 1957.

American National Standards Institute. Criteria for background noise in audiometer rooms. ANSI S3.1, 1960.

American National Standards Institute. Specifications for audiometers. ANSI S3.6, 1969.

American National Standards Institute. Specification for protective headgear for vehicular users. ANSI Z90.1-1971/Z90.1A-1973.

Billings, B. L. Real ear attenuation study: Super high-G aircraft flight helmet. Audiology Center of Redlands Medical Clinic, Inc., Aug 1976.

Camp, R. T., et al. Letter Report USAARL LR 75-18-2-8, Nov 1974. (Makes reference to Minimum Acceptable Attenuation Values for U.S. Army Tank Helmets (page 1).)

Flugrath, J. M., and J. B. Turbeville, Jr. The effectiveness of earplugs. Sound and Vibration, May 1972.

Flugrath, J. M., and B. N. Wolfe. The effectiveness of selected earmuff-type hearing protectors. Sound and Vibration, May 1971.

Lindsey, J. L. Vought Corporation. Report LSWT 513, Determination of windblast forces and moments on the Sierra Engineering Co. super high-G helmet, 29 Nov 1976.

Military Specification. Helmet shell, flying, HGU-22/P. MIL-H-83147 USAF, 24 June 1968.

North Atlantic Treaty Organization. AGARD Conference Proceedings No. 170, Biodynamic response to windblast, July 1975.

Sierra Engineering Co. Technical Proposal No. 570-942, Super High-G Helmet, March 19, 1976.

USAF School of Aerospace Medicine. Preliminary Report, USAF evaluation of the Sierra Lightweight Helmet, 1977.

GLOSSARY OF TERMS

Aerodynamic and Model Dimension Symbols

Symbol	Definition
A	Axial force, pounds
b	Reference length, feet (b = 1.0)
c	Reference length, feet (c = 1.0)
C.G.	Moment Reference Center
C_A	Axial force coefficient, A/qS (Axial force area)
C_ℓ	Rolling moment coefficient, ℓ/qSb (Rolling moment volume)
C_m	Pitching moment coefficient, m/qSc (Pitching moment volume)
C_N	Normal force coefficient, N/qS (Normal force area)
C_n	Yawing moment coefficient, n/qSb (Yawing moment volume)
C_Y	Side force coefficient, Y/qS (Side force area)
ℓ	Rolling moment, foot-pound (inch-pounds in data printout)
M	Mach number
m	Pitching moment, foot-pounds (inch-pounds in data printout)
n	Yawing moment, foot-pounds (inch-pounds in data printout)
N	Normal force, pounds
P_{BARO}	Barometric pressure, inches of mercury
q	Test section dynamic pressure, pounds per square foot
q_{set}	Piezometer ring differential pressure
R_N	Reynolds number per foot
S	Reference area, square feet (S = 1.0)
T_o	Test section stagnation temperature, ^oF
V	Test section flow velocity, feet per second
Y	Side force, pounds
[illegible]	Model pitch angle, degrees
[illegible]	Model yaw angle, degrees

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