5.4 Retention systems

The helmet retention system is critical for head impact safety by securing the helmet snugly to the wearer's head. Several improvements have been made in the helmet retention systems. Table 5 provides a brief discription of the different systems utilized in the Army aviation helmets.

Table 5. Helmet retention systems.

Helmet	Type system
APH-5	separate
SPH-4	harness
IHADSS	integral
SPH-4B	harness
HGU-56/P	integral

The APH-5 utilized separate straps for the chin and nape straps. Each of these attached separately to the helmet shell. This configuration is considered inadequate because retention system effectiveness is dependent on the helmet shell stiffness and the mounting locations of the strap to the shell.

The SPH-4 and SPH-4B helmets utilize a harness configuration which contain the earcups. These two harnesses are shown in Figures 9 and 10. The original SPH-4 design was poor because the chinstrap load was carried through four attachment tabs, the webbing containing the earcups, and finally to the chinstrap itself. Failures occurred at the tab and webbing or the chinstrap and webbing attachment points. The pull-the-dot chinstrap fasteners also caused helmet loss. The SPH-4B utilized an improved design by routing the chinstrap webbing directly to the helmet shell. Thus, chinstrap loading was through a continuous piece of material instead of multiple links. The harness material containing the earcups could also be adjusted in length to pull against the wearer's nape. When properly adjusted, the nape increased the helmet's stability and retention characteristics.

Figure 9. SPH-4 retention harness.

Figure 10. SPH-4B retention harness.

The IHADSS helmet retention system is similar to the SPH-4B system. Its chinstrap connects to the lower portion of a "V" strap. The upper legs of the "V" strap attach directly to the helmet shell and provide stability. The rearward strap weaves through the harness material which contains the earcups. This material wraps around the wearer's nape and can be adjusted snugly to improve helmet stability.

The HGU-56/P also utilizes a chinstrap which attaches to a "V" strap similar to the IHADSS and SPH-4B. The difference is that no harness is used to contain the eacups. The earcups are attached to the "V" straps with Velcro®. The "V" straps are also integrated with the nape strap pad with adjustable webbing. This configuration yields a low elongation chinstrap assembly and a stable helmet when properly adjusted.

The method used to attach the chinstrap is critical. Single snap fasteners, as used on the APH-5 and original SPH-4s, allowed frequent helmet loss in survivable mishaps [6,7]. Double snaps improved retention performance, but did not eliminate helmet loss. The SPH-4B and HGU-56/P both utilize only double D-rings for the attachment and adjustment of the chinstrap.

5.5 Earcups

The APH-5 helmet utilized foam earcups and provided little ambient noise attenuation. The SPH-4 provided much improved sound attenuation by utilizing thick and rigid earcups. A cross section view of a standard SPH-4 earcup is shown in Figure 11.

Through the USAARL ALSERP, it was recognized that aircrew basilar skull fractures were often accompanied with fractured earcups [8]. Static testing of the standard SPH-4 earcup revealed fracture occurred at over 22,000 Newtons. Yet, the temporoparietal region of the human skull can fracture under loads half as great [9].

The IHADSS helmet contains earcups that are rigid, but fracture at loads below the standard SPH-4 earcups. The SPH-4B and HGU-56/P helmets both contain crushable earcups which yield at loads below human threshold. Crossectional views of these earcups are shown in Figures 12 and 13.

Figure 11. SPH-4 earcup, cross section.

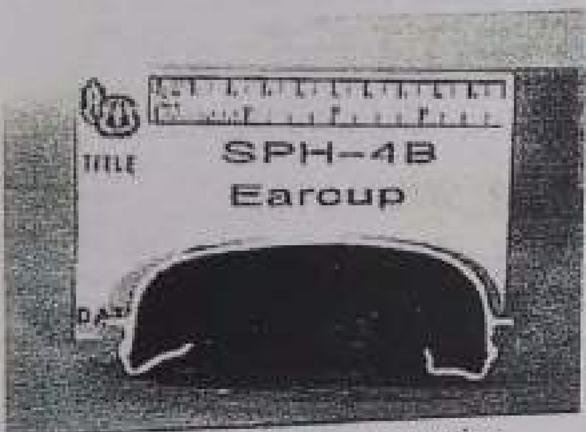

Figure 12. SPH-4B earcup, cross section.

Figure 13. HGU-56/P earcup, cross section.

5.6 Visor systems
Visor systems have experienced little change except for graduating from a single visor design in the SPH-4 and IHADSS to a dual visor design in the SPH-4B and HGU-56/P. The dual visors are preferred by aircrew since it provides an option of a clear visor during low daylight situations and a smoke visor during daylight operations. Single visor design forced the aircrew to select a visor prior to flight or risk eye injury if they decide not to deploy the visor. Both the clear and the smoke visors filter at least 98 percent of ultraviolet rays [10]. Visor use is important as it protects the eyes from flash fires, flying debris, and impact during crashes. Early visors were made from acrylic and frequently fractured when impacted. Current visors are made from polycarbonate and rarely fracture.

5.7 Ancillary equipment
Depending on the mission and the aircraft being flown, various ancillary equipment can be used with aircrew helmets. Listed in Table 6 are the helmets and various compatible pieces of equipment.

The oxygen mask requirement is necessary because of high altitude missions (greater than 10,000 feet) in mountainous regions. Usually these missions are associated with the special operation forces and emergency rescues.

The PNVS-5 is an early generation night vision goggle which has been replaced with the ANVIS-6 goggle. These devices are necessary to reduce risk when missions are required to be conducted at night.

The threat of chemical and biological warfare necessitate the requirement for chemical and biological protective respirators (CBR mask).

Table 6. Helmet ancillary equipment.

Helmet	Compatible equipment
APH-5	Oxygen mask
SPH-4	AN/PVS-5, ANVIS-6, oxygen mask, CBR mask, AH-1 mechanical tracking& targeting system
IHADSS	AH-64 Infra-red head tracker & HDU, CBR mask, ANVIS-6
SPH-4B	PNVS-5, ANVIS-6, oxygen mask, CBR mask, AH-1 mechanical tracking& targeting system
HGU-56/P	ANVIS-6, oxygen mask, CBR mask, AH-1 mechanical tracking& targeting system, AH-64 Infra-red head tracker & HDU

The AH-1 and AH-64 helicopters both have weapon systems capable of being aimed by sensing the position of the helmet in the cockpit. The AH-1 Cobra uses a mechanical linkage attached directly to the helmet to measure the helmets position and orientation. The AH-64 Apache uses infra-red sensors mounted on the helmet to sense orientation.

6. PROTECTIVE REQUIREMENTS
The basic protective requirements for the Army helicopter aircrew helmet have become more stringent in an effort to improve aircrew safety. These requirements include impact, retention, tear resistance, and sound attenuation.

6.1 Impact protection
The helicoper aviator helmet protective requirements have

received considerable changes over the past 30 years. Table 7 provides some basic details on the requirements for each helmet. The APH-5 is not included in this table since its impact requirements were based on the "swing away" test method and are not comparable to the other helmets.

The HGU-56/P has the most stringent impact requirements. These requirements are also applicable to the RAH-66 Comanche helmet development efforts.

Table 7. Impact performance requirements.

Helmet	Impact site	Impact velocity (m/s)	Peak accel (G)
SPH-4			
flat	all	5.3	400
hemi	all	5.3	400
SPH-4 (1982)			
flat	all	5.3	300
IHADSS			
flat	all	5.3	300
SPH-4B			
flat	earcups	6.0	175
flat	other areas	6.0	250
HGU-56/P			
flat	crown	4.9	150
flat	earcup	6.0	150
flat	headband	6.0	175

The headband region acceleration threshold of 175 G was placed in order to prevent concussion to Army crewmembers in survivable mishaps [11]. Surviving a military mishap with a concussion is unacceptable due to potential hazards associated with military crash environments. Unconciousness could lead to an aviator's drowning or capture, depending on the crash location (water or enemy teritory) or burns in the presence of a postcrash fire. Aircrew must remain concious during survivable mishaps to quickly egress the crashed aircraft, provide assistance to fellow crewmembers, and evade hostile search parties.

The 150 G requirement for the crown and earcup region were established to reduce the potential of basilar skull fractures when impacted at those sites [11]. The impact velocity for the crown impact was reduced because direct blunt crown impact at the greater velocity rarely occurs in survivable mishaps.

Impact tests are required to be conducted on a guided free-fall drop tower assembly configured in accordance with the American National Standards Institute ANSI Z90.1-1971 [12]. The USAARL helmet impact tower is shown in Figure 14.

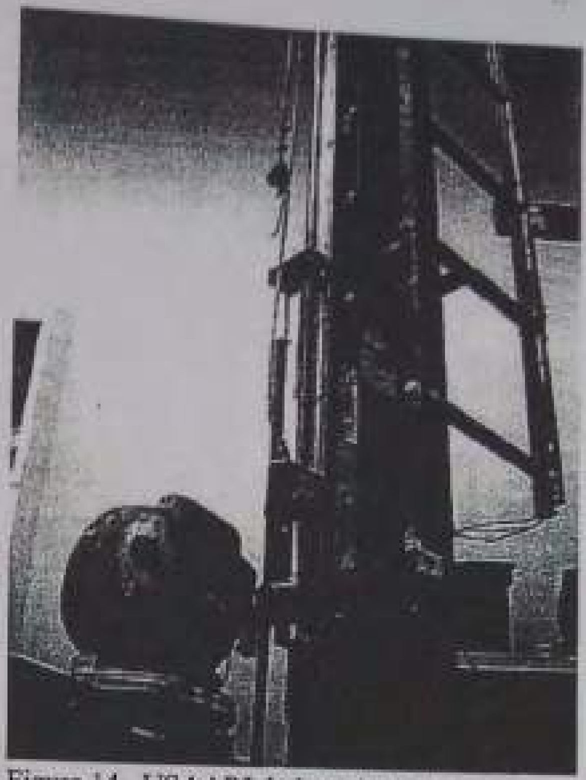

Figure 14. USAARL helmet impact tower.

For the crown and headband impacts, headforms conforming to the Department of Transportation (DOT 218) size B, C, and D are used. Impacts to the earcup region require use of a modified size C headform. This modification includes the downward extension of the headform in the earcup region to increase the contact surface area. Material is removed from the inner surface of the headform to maintain the mass requirement of the size C headform.

All impacts for performance assessments are conducted onto flat impact anvils. The hemispherical anvil was eliminated after ALSERP investigators revealed less than 3 percent of helmet impacts resulted from hemispherically shaped objects, while flat surfaces accounted for over 60 percent [6].

6.2 Helmet retention

Helmet retention assessments are necessary to ensure the basic helmet system, if fitted and worn as designed, will keep the helmet properly positioned on the wearer's head. The Army currently requires only a static strength assessment be performed. In addition to the static test, USAARL routinely conducts dynamic retention tests for comparative purposes.

6.2.1 Static

The static retention test is conducted in accordance with ANSI Z90.1-1979 [13] with one exception, the preweight is 25 pounds instead of 50 pounds. As illustrated in Figure 15, this test requires a static load be applied through a simulated chin onto the chinstrap. The maximum strength and elongation requirements are provided in Table 8. Inspection of Table 8 reveals an increase in static strength

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requirements. Again, this is a result of ALSERP findings of chinstrap and harness failures in accident helmets [6,7].

Table 8. Static retention requirements.

Helmet	Static strength (pounds)	Maximum elongation (inches)
APH-5	150	no separation
SPH-4	150	no separation
SPH-4 (1982)	300	no separation
IHADSS	300	no separation
SPH-4B	440	1.5
HGU-56/P	440	1.5

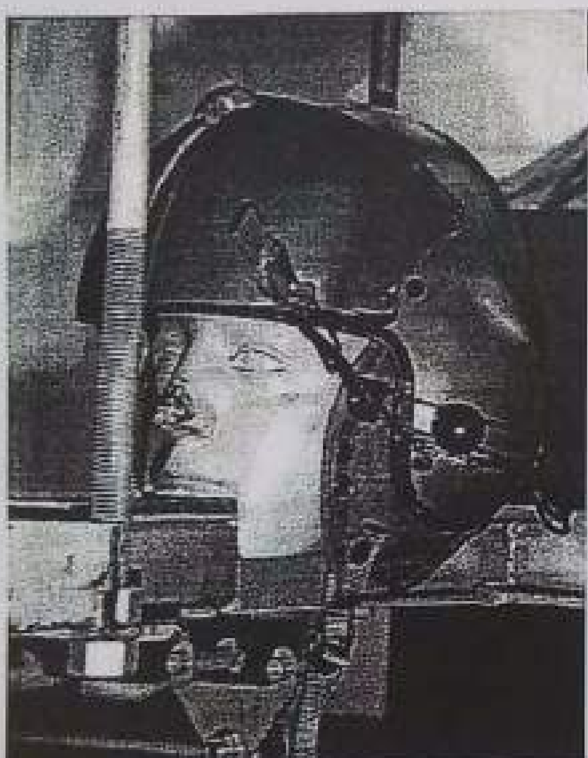

Figure 15. Chin strap static pull test setup.

6.2.2 Dynamic

The dynamic retention tests are conducted on a pendulum test device which has a Hybrid II head attached to a Hybrid III manikin neck at the end of the pendulum. Triangular shaped impact pulses from 10 to 15 G up to 25 to 30 G are applied to the pendulum beam in a rearward direction to the headform (a forward impact). The dynamic response of the helmeted head is recorded on video at 1000 images per second. Digitization of this data reveal relative angular displacements between the helmet and head. The test setup is shown in Figure 16. Graphical results of a prior study are provided in Figure 17. No absolute pass and fail criteria currently exist for dynamic retention performance. New systems and modifications are compared to the standard SPH-4B and HGU-56/P aircrew helmets.

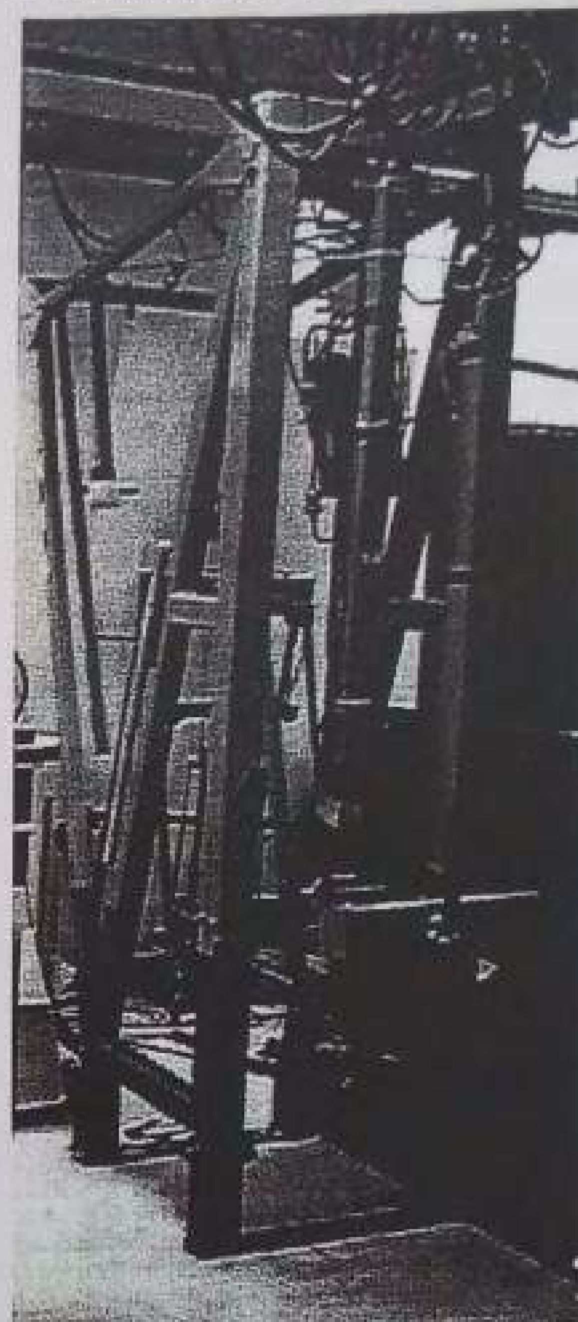

Figure 16. Dynamic retention pendulum tower.

6.3 Shell tear penetration

As a measure of shell integrity, a helmet shell tear penetration test is required on the HGU-56/P [11]. This requirement was not placed on any other helmet configuration, but the performance levels were established by testing standard SPH-4 (fiberglass) helmet shells.

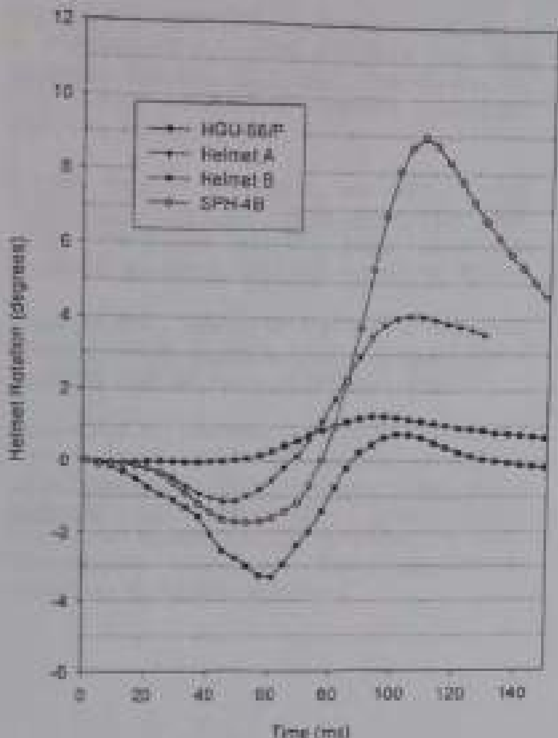

Figure 17. Dynamic retention test results.

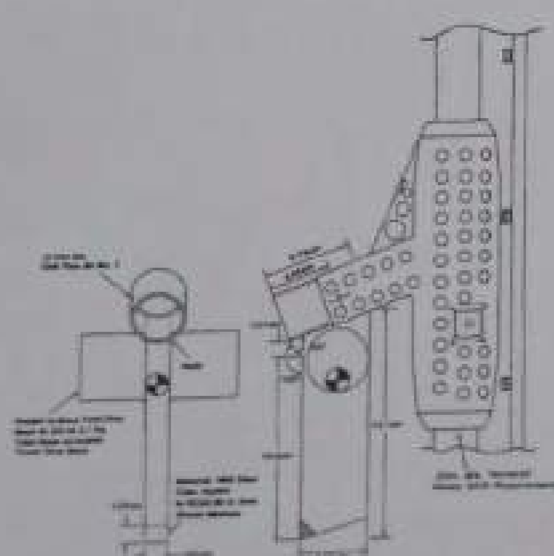

Figure 18. Helmet tear test penetrator.

The requirement is to drop a tear penetrator (shown in Figure 18) weighing 5 kg from a drop height of 1.52 meters. If the penetrator creates a tear length (measured along the shell surface) greater than 5 cm, the shell fails. The SPH-4 fiberglass helmet shells performed at this level. The SPH-4B Kevlar® shell and the IHADSS composite shell both fail to meet this requirement. This setup essentially tests the shell material in shear, in which graphite and Kevlar® perform poorly. The SPECTRA® rarely allows tearing to initiate, but allows the shell to buckle unless it is rigidly supported on its underside.

6.4 Sound attenuation

The ability of aviator helmets to reduce ambient noise levels remains a primary requirement. The performance requirements do not represent desired limits based on aircraft noise environments and human tolerance to exposure levels, but a reflection of state of the art performance. Table 9 provides the performance requirements of the HGU-56/P helmet when tested in accordance with ANSI S12.6-1984 [14]. To supplement the basic helmet performance, earplugs are required to be worn under the aviator helmets.

Table 9. Sound attenuation requirements.

Frequency (hz)	HGU-56/P (dB)
125	17
250	14
500	20
1000	21
2000	26
3150	38
4000	37
6300	44
8000	42

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removido da superfície interna do formato da cabeça para manter o requisito de massa do formato de cabeça de tamanho C.

Todos os impactos para avaliações de desempenho são realizados sobre bigornas de impacto plano. A bigorna hemisférica foi eliminada após investigadores do ALSERP revelaram que menos de 3% dos impactos de capacete resultaram de objetos afiados hemisféricos, enquanto as superfícies planas responderam por mais de 60% (6).

6.2 Retenção de capacete

As avaliações de retenção de capacete são necessárias para assegurar que o sistema básico do capacete, se adaptado e usado conforme projetado, mantenha o capacete posicionado de modo apropriado na cabeça do tripulante.

O Exército atualmente exige apenas que seja executada uma avaliação de resistência estática. Em adição ao teste estático, o USAARL rotineiramente realiza testes de retenção dinâmica para finalidades de comparação.

6.2.1 Estática

O teste de retenção estática é realizado de acordo com ANSI Z90.1-1979 (13) com uma exceção, o pré-peso é de 25 libras em vez de 50 libras. Conforme ilustrado na Figura 15, este teste exige que uma carga estática seja aplicada através de um queixo simulado na correia do queixo. Os requisitos máximos de resistência e alongamento estão fornecidos na Tabela 8.

A inspeção da Tabela 8 revela um aumento nos requisitos de resistência estática. Novamente, isto é um resultado das constatações do ALSERP de falhas da correia do queixo e do conjunto de correias em capacetes acidentados (6,7).

Tabela 8. Requisitos de retenção estática.

Capacete	**Resistência estática (libras)**	**Alongamento máximo (polegadas)**
APH-5	150	Sem separação
SPH-4	150	Sem separação
SPH-4 (1982)	300	Sem separação
IHADSS	300	Sem separação
SPH-4B	440	1,5
HGU-56/P	440	1,5

[Consta figura]

Figura 15. Configuração do teste de puxão estático da correia do queixo.

6.2.2 Dinâmica

Os testes de retenção dinâmica foram realizados em um aparelho de teste de pêndulo que tem uma cabeça Híbrida II fixada ao pescoço do manequim Híbrido III na extremidade do pêndulo. Os pulsos de impacto de forma