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NATO ARMY ARMAMENTS GROUP (NAAG)

HEAD BORNE SYSTEMS FOR DISMOUNTED SOLDIER SYSTEM

Note by the Staff Advisor

Ref.: **1. AC/225(DSS)DS(2023)0001, LCGDSS Spring 2023 Meeting**
2. AC/225(DSS)D(2016)0006, Head Borne Systems for Dismounted Soldier Systems
LAMP Reference: DSS-006

1. The Head Borne Systems (HBS) for Dismounted Soldier System (DSS) is a document produced by the Head Borne Systems Team of Experts (HBS TOE), stood up by Land Capability Group Dismounted Soldier System (LCGDSS) in March 2012.

2. This document is published per action of Ref.1, to review the state-of-the-art in head borne systems relating to Soldier System interoperability.

3. The aim of this document is to capture and reflect the planned modernisation relevant to head borne systems. It will be a central reference across the NATO LCGDSS sub-groups to identify and direct the development of STANAGs/STANRECs to promote interoperability.

4. This document is reviewed every five years. This version replaces and invalidates Ref.2, published in March 2016.

5. The HBS for DSS document is submitted to the approval of LCGDSS under a silence procedure until 20 June 2023.

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<u>HEAD BORNE SYSTEMS FOR A DISMOUNTED SOLDIER SYSTEM</u>

1. RELATED DOCUMENTS AND BODIES

For related military references see Annex A.

Related NATO bodies include:

- NAAG Groups
  - Land Capability Group Land Engagement (LCGLE)
  - Joint CBRN Defence Capability Group (JCBRNDCDG)

- Within LCGDSS
  - Combat Clothing, Individual Equipment, and Protection (CCIEP)
  - Soldier Capability Analysis Group (SCAG)
  - C4I and Soldier Architecture
  - Soldier Power
  - Weapons and Sensors (W&S)
  - Human Systems Integration (HSI)

2. AIM

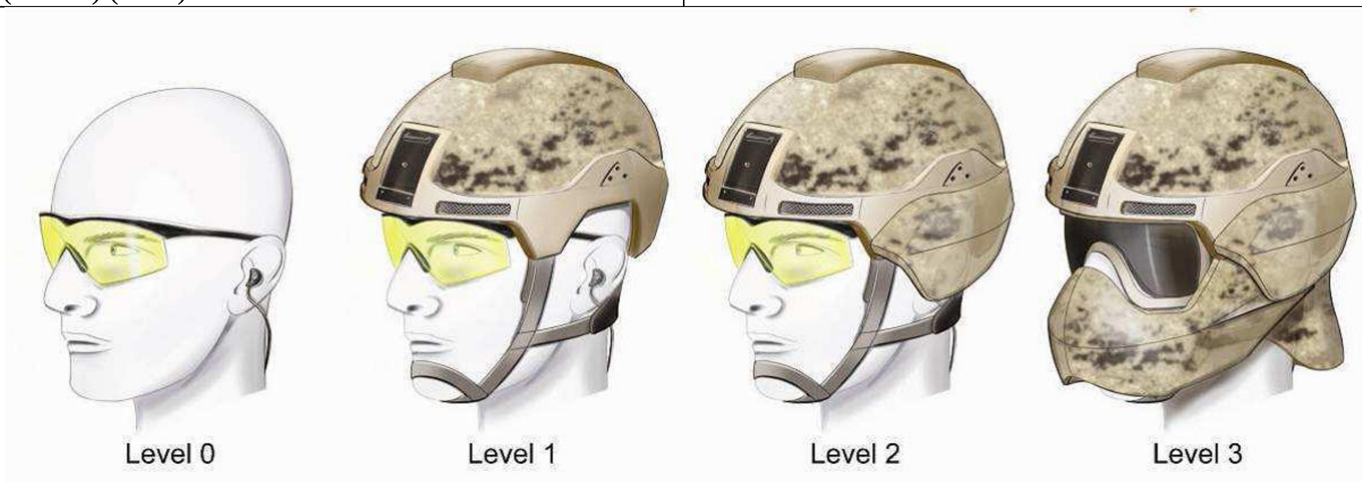
The aim of the Head Borne Systems (HBS) Interoperability Document is:

1. To identify and describe the interoperability issues of HBS in the framework of a Dismounted Soldier System (DSS);
2. To define the responsibility of NATO and of the DSS-producing nation with respect to HBS interoperability issues;
3. To define the characteristics of integrated HBS and their relationship with interoperability issues;
4. To define a progressive standardisation priority list for HBS.

As military helmets evolve to form an integral part of the soldier system, providing not just personal protection, but also a head borne "hub", providing power and data for capability enhancing equipment and sub-systems, nations need to ensure that the integration and standardisation of that capability is considered. This includes physical, cognitive, architectural and system integration. A number of examples of varying nations' and commercial off the shelf (COTS) helmet system developments are illustrated in Figure 1.

Figure 1 – Example of Integrated Head Borne Systems

	
UK Future Soldier Vision 2014 Integrated Helmet Concept - Integrated 3D sound, active hearing protection and sensor suite	UK Future Soldier Vision 2 2016

<table>
<tr><td></td><td></td></tr>
<tr><td>UK DefStan 23-12 Compliant Helmet as a Platform (HAAP) (2016)</td><td>UK Integrated Helmet System (IHS) (2022)</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">Netherlands Integrated Helmet Concept (2014)</td></tr>
</table>

Galvion Caiman® Next Generation – Used by Permission from Galvion

Netherland DOCKS helmet (2023)

Gentex RAILINK® helmet

3. NATO STANDARD EXPRESSION FOR HEAD BORNE SYSTEMS FOR A DISMOUNTED SOLDIER SYSTEM

The equipment worn on the head is considered a system of functional parts (or system of systems). HBS incorporate a large number of functions that are currently provided by a set of separate and not necessarily fully compatible parts, such as those listed in Table 1.

Table 1 - Dismounted soldier head borne equipment

Helmet shell	Communication head set
Visor	Hearing protection
Mandible guard	Digital Magnetic Compass (DMC)
Respirator	Head Mounted Display (HMD)
Filter canister(s)	Hood
Glasses	Night vision goggles/device
Ballistic / dust goggles	Directed energy recorded/warning
Corrective lenses	Combat ID (CID) systems
Thermal net or cover	Connectors
Infra-red net or cover	Exoskeletons
Batteries/power source	Gyroscope
Cables	Heads-up display
Global Positioning System (GPS)	Video/image capture
Laser threat warner/recorder	

A correctly designed and tested HBS can expand the range of functions, improve compatibility, reduce burden (physical and cognitive), increase user acceptance and increase operational effectiveness.

The NATO LCGDSS HBS Team of Experts (ToE) define a HBS as:

"A Head Borne System is any incorporated set of equipment worn on the head and meant to work independently or in concert with other components or sub-systems of a Dismounted Soldier System (DSS)."

For the clarity of this document, the HBS is regarded as a system (with sub-systems, modules, components and other parts), despite other terminology that may be used elsewhere:

***Dismounted Soldier System (DSS)*:** the DSS encompasses everything that the Soldier carries, uses, or consumes. A systems approach ensures that all elements of the DSS have been designed with optimisation and integration in mind.

***Modules*:** physical parts of an HBS that can be detached or mounted by the user to configure the HBS for a specific operational task.

***Components*:** physical parts of an HBS that can be detached or mounted by service personnel for the purpose of repair or for enabling functions.

***Family of HBS*:** a set of HBS that optimise the sharing of modules and components between models in the family.

Functions: properties of an HBS that enable the execution of specific operational tasks, or that achieve certain goals.

Platform functions: use of an HBS as a carrier or mount for modules or components.

Protective functions: properties of an HBS that provide protection from hazards.

Ergonomic functions: properties of an HBS that reduce the workload on the user and improve the wearability.

Operational functions: properties of HBS that cater for operational needs.

Functionality: set of functions required alone or in combination to fulfil an operational requirement.

Sub-system: physical embodiment of functionality.

Integration: the effort of combining and optimising functions in an HBS with the purpose of increasing operational performance while minimising weight, space, and power requirements of the system.

Interoperability (national): the ability to exchange and use equipment with NATO allies in a seamless manner to provide *system interoperability*.

Interoperability (system): the ability for the HBS or sub-systems of the HBS to provide functionality and capability without physical (or other) interference, or the ability of the system to perform at a minimum agreed requirement.

Service life: the time for which an item, in specified storage environmental conditions and when subsequently used in its specified operational and/or training conditions, may be expected to remain suitable for service. Service Life is the sum of Storage and Operational Life.

Storage life: the time for which an item, in specified storage conditions, may be expected to remain safe and suitable for service.

Operational life: the life of an item in operational use and training.

Notes:

1. For certain items, the cumulative periods of time spent in storage or operational environments are not recorded or differentiated between and it would not be cost-effective to introduce such recording. In these instances, the term 'Service Life' may be used to define the total period of time an item may be kept in service before disposal or being expended.

2. For items entering service, it is often necessary to assess an initial Service Life that is subsequently subject to extension.

4. LIST OF APPLICABLE NATO STANDARD TYPES OF HEAD WEAR

No standard NATO helmets exist, but most nations discern the following types:

- **Combat helmet**: designed for protection against fragmentation created by the dynamics of combat, some pistol rounds, high velocity rifle rounds, and low level blunt impact (so-called bump protection). Available in numerous shapes and levels of head coverage or "cuts";

- **Combat vehicle crew (CVC) helmet**: provides protection from fragments, possibly at a lower level and or with less coverage than an infantry helmet to reduce weight, and low level blunt impact, possibly at a higher level. Allows integration of high attenuation hearing protection;
- **Combined combat/CVC helmet:** designed to provide the same level of ballistic and non-ballistic protection as a combat helmet, with the coverage, non-ballistic impact resistance and accommodation of hearing protection/communication devices required for CVC helmets;
- **Airborne helmet**: generally lighter than infantry helmet to mitigate neck injury risk when parachuting, and with a particular focus on eliminating snag hazards and chinstrap buckle release loads. This helmet may be combined with a combat helmet;
- **Explosive ordnance helmet**: greater or complete coverage of the head provided due to the enhanced threat, at the expense of reduced situational awareness, increased mass and physiological burden, and reduced mobility.

Combat helmets are frequently modified to allow the mounting of equipment; in particular head mounted displays, night vision goggles, and facial protection systems. In peace support operations soft headwear may be worn rather than combat helmets. However, some of the functionality of an HBS (such as enhanced vision, audio and visual displays, and microphones) may still be required, leading to a potential requirement for multiple attachment systems.

5. IMPLEMENTATION OF HBS

Military performance issues due to physical equipment integration have been recorded universally, in particular where items have been developed independently without full consideration of integration with, and onto, the Dismounted Soldier System.

5.1 The Concept of HBS in a Soldier Systems

Soldier Systems consist of many modules and components designed to work together as an integrated system, with the Soldier at the centre of that system. The HBS consists of modules that provide the functionalities required to achieve mission success. Currently, the engineering state of the art is that modules tend to provide functions, and often only one. The expectation is that in the future these modules will be better integrated to provide several functions rather than individual functions. It is speculated that as Soldier Systems develop and evolve, possibly only a few major Soldier Sub-Systems will remain – the weapon, the head, and the combat vest. It is this expectation that justifies the early investigation of interoperability issues of HBS, with the head being a sub-platform of the Soldier System platform.

5.2 The Requirement for Integration

The central requirement of the successful development and deployment of an HBS is integration. Integration of multiple functionalities into a system of systems provides two significant operational advantages:

1. Compatibility is optimised and overall weight and bulk be reduced[1];
2. Alternately, better integration can allow greater functionality within the physiological limits of head borne weight than would otherwise be possible. Recent evidence from both the US[2] and UK[3] points

[1] Including Size, Weight and Power (SWaP).
[2] Estep. P.N., et al. Mass Properties Comparison of Dismounted and Ground-Mounted Head-Supported Mass Configurations to Existing Performance and Acute Injury Risk Guidelines. Military Medicine, 184, 3/4:245, 2019.
[3] Maximum Helmet Weight – A Literature Review for the Dismounted Close Combat Domain. DSTL/TR52274 v1.0. May 2011.

towards 1.5 kg as the potential upper threshold for user acceptance of a helmet, with further literature indicating that this may also form an upper safe limit for head mounted mass under certain circumstances.

5.3 The Need for Improved HBS

The fact that the head is the focus of human perception, and a vulnerable element of the human, creates a need for a variety of protective systems and information aids that all focus on this small area of the body. Among the equipment items to be accommodated on the head are: helmet, respirator, goggles, laser and hearing protection for the protective functions, and eye correction, head mounted display and communications head-set for information exchange (see Table 1). Some other devices may also be head mounted, such as an image intensifier or Combat Identification (CID) device. These items need to be compatible with each other, need to fit (physically) on the head, and comply with other equipment such as CBRN clothing, ballistic vest and gloves. There is currently no satisfactory solution for the simultaneous combined use of all these items, and there are additional protective requirements to be fulfilled. The head is quickly physically overloaded and Soldiers' performance may decline due to ergonomic problems.

5.4 Standardisation and Innovation

From an interoperability viewpoint, a timely study of standardisation of an innovative product such as an integrated HBS has merits and drawbacks. One drawback is that choices associated with design boundary conditions may be made at a time when the technology is immature and operational experience is very limited. This study thus has to consider likely developments in the near future. One of the merits is the argument that standardisation should be sought before national developments and procurement decisions preclude the possibility of coming to an agreement.

AEP 2902 Non-Ballistic Test Methods and Evaluation Criteria for Combat Helmets Edition A Version 1 aims to standardise all helmet related protection test methods and physical connectivity. This interoperability document will be used to identify opportunities to update AEP 2902 to ensure its relevance in the future.

5.5 HBS Experience

The concept of an integrated HBS for army use is relatively new and no nation has yet fielded such a product. Experimental products have been shown in NO, US, UK, NL, CA and FR. In military aviation, integrated HBS are common. However, the threats, tasks and functionality in aircraft are so different from land use that this experience is difficult to apply directly to land use. Relatively simple integrated HBS are common in the civil sector, such as in motorised sports and emergency services. These differences are expanded, below.

5.6 Operational Reasons

A single design of HBS cannot possibly cater for all of the variations in military helmets. Usually, distinction is made between combat helmets, CVC helmets, paratrooper helmets and variations related to specific military units and their typical environments (e.g., Marines, Rangers, Mountain troops, etc.). The role of the Soldier is strongly conveyed by his outward appearance, so the HBS may have to be tailored between peacekeeping operations and combat operations.

Whilst some nations have conducted research into multi-role helmets, some requirements (e.g. blunt impact) can contradict one another.

5.7 Functional Reasons

The HBS is to be designed for combat Soldiers. However, it may be desirable to provide some troops with a helmet that provides less capability whilst achieving acceptable levels of protective performance. These troops may have no need for some sub-systems. It is desirable that these can be easily left out or disassembled, while the other sub-systems remain working.

5.8 Flexibility and Cost

For reasons of economy, larger numbers could be beneficial for both customer and producer. It seems likely that a family of designs that use common components and mounting systems would yield economies of scale, interoperability of head mounted equipment between nations, and allow upgradable components to a helmet "chassis" as technology advances.

6. PERFORMANCE OBJECTIVES OF A HBS

A single physical design of HBS cannot cater to all possible roles for a military helmet or each nation's political appetite for risk. Infantry, combat vehicle crew, paratrooper, Marine's, Ranger's, mountain troops, etc. dictate requirements for unique characteristics, functionality, and role specific trade-offs in performance dependent on their unique operational environments. This is not to say that a level of commonality cannot be achieved between two or more of these user groups requirements, but a single, 'one size fits all' helmet system would require compromises in performance and capability that would result in a HBS that may not meet the operational requirements of any one of the user communities. More feasible is a family of HBS sharing common sub-systems but with specific functionality and performance for a given mission profile.

The guiding principal of design for any HBS must be integration of open architectures: integration of the various sub-systems that provide the desired suite of functionalities whose power, data and physical interface are non-proprietary; integration of the resulting HBS with the rest of the Soldier System; and perhaps most importantly, integration with the Soldier. The objective is to maximise functionality while minimizing the physical and cognitive burden on the wearer in order to ensure operational effectiveness. The specific functionalities that are desirable for a HBS are detailed in the following sub-sections.

6.1 Reduced Bulk and Weight

The goal of any HBS is to equip Soldiers with a modular and scalable/mission-tailorable protection system at reduced weight and increased mobility while optimizing protection. A lightweight and modular design concept will enable Soldiers to modify their protective status based on commander's guidance, mission, and environment. Scalable levels of protection will reduce the Warfighter's susceptibility to injury and enhance mission performance by allowing commanders to shape the Soldiers' protective posture to address multiple, changing threats. Reduced HBS weight is achieved primarily by material technology advances, and by modularity and scalability that allows the Soldier to carry only the mission required protection and functional capabilities. Reduced bulk is important for the operational implications, as well as the placement of weight within the HBS (i.e. for optimal centre of mass).

6.2 Improved Protection

There is a strong desire to provide as complete coverage as possible of the head and neck in a HBS. Penetrating, concussive (impact), and thermal injuries to the head and neck are generally associated with high risks of mortality and, at the very least, significant reduction in operational effectiveness. The level of protection that can be provided is largely constrained by two factors: ergonomics (including physiological burden) and situational awareness. Availability of advanced, lightweight protective materials technologies is often viewed as the limiting factor in addressing these constraints, as well as the risk posed by behind helmet blunt trauma (BHBT).

Modular HBS sub-systems can be applied to allow greater protection/coverage, but there are still technological limitations. For example, facial protection could be used to provide more uniform protection levels over the entire head. However, the development of lightweight, optical quality transparent armour technologies which provide protection levels comparable to the materials used in helmet shells continues to be a significant challenge. Furthermore, even if the desired ballistic performance were to be achieved, their application in a HBS would be limited by the durability (e.g. scratch resistance) of the materials. Equally important is the requirement for effective control of the thermal load and moisture management. Fogging of visors after minimal exertion can render a facial protection system completely ineffective, as can scratching of the lens. Situational awareness will dominate and the protection system will not be worn.

The example presented above serves to illustrate one of the most significant challenges in providing increase protection; a protection system not worn provides no protection at all. The provision of improved protection is a multidisciplinary endeavour.

6.2.1 Fragmentation

The modern combat helmet can be traced back to a basic requirement for fragmentation protection from shell fragments. Over time, the level of protection that can be afforded within the physiological limits of the head and neck has steadily increased due to advances in the performance of protective materials. The HBS should provide a level of protection against fragmentation that is at least comparable to the fragment protection provided by other components of personal protective equipment in the Soldier System, e.g. vest. Not only must the HBS prevent penetration by the fragment, it must also mitigate the resulting back face deformation of the helmet shell in such a way as to mitigate BHBT from both fragments and/or bullets. The range of fragment sizes and energies that must be mitigated by the HBS are based on an assessment of the operational threat and risk of injury.

6.2.2 Blast

Understanding the effects of exposure to blast, and the role of the HBS in mitigating possible injuries to the central nervous system, is currently an area of significant research and development. There are indications that increased coverage, in an integrated HBS protection system, may provide increased protection. Providing coverage of the face and maintaining or extending coverage on the sides and at the back of the helmet are desirable, although this presents physiological and ergonomic challenges to the HBS design. The helmet suspension system also appears to play a role in decoupling the head reaction from impulsive loading generated by blast overpressure. More research is needed in this area to identify the dominant protective system characteristics and define specific performance requirements.

6.2.3 Blunt Impact

Combat helmets typically provide a relatively low level of blunt impact protection (sometimes termed ‘bump protection’) compared to helmets designed for this specific purpose, for example, mountaineering helmets or industry safety helmets.

Helmets specifically designed for vehicle occupants and parachuting (vs. for dismounted operations) and helmets designed for multiple roles commonly require a higher level of impact energy attenuation compared to dismounted combat helmets. Increasing blunt impact protection is desirable but may come at the cost of (for example) increased shell size to accommodate thicker energy absorption helmet liners, thereby increasing weight and head silhouette. Whilst there are accepted injury criteria for head impacts (Head Injury Criterion[4], and Wayne State Tolerance Curve[5]), there is not a consensus on medical community validated and injury correlated blunt impact requirements for HBS used by dismounted combatants, with may NATO nations adopting either a peak or average head acceleration related to the Wayne State Tolerance Curve.

Rotational injuries and their associated test methods and metrics are currently being investigated for combat helmets, and AEP 2902 will be updated to include these metrics when applicable. A caveat is the effect the simultaneous use of other head mounted

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[4] Hans-Wolfgang Henn, Crash Tests and the Head Injury Criterion, Teaching Mathematics and its Applications: An International Journal of the IMA, Volume 17, Issue 4, December 1998, Pages 162–170, https://doi.org/10.1093/teamat/17.4.162.

[5] Namjoshi DR, Good C, Cheng WH, Panenka W, Richards D, Cripton PA, Wellington CL. Towards clinical management of traumatic brain injury: a review of models and mechanisms from a biomechanical perspective. Dis Model Mech. 2013 Nov;6(6):1325-38. doi: 10.1242/dmm.011320. Epub 2013 Sep 12. PMID: 24046354; PMCID: PMC3820257.

equipment has on the protection towards blunt impact.

6.2.4 Handgun / Fragment Protection

Helmets have provided handgun ball and fragment protection for a number of years. Whilst the back face deformation against fragments is seldom measured, the back face deformation from handgun projectiles can be injurious.

A helmet that provides handgun protection must not only prevent perforation of the shell but must also limit back face deformation (BFD) and manage the energy transfer to the skull. There are no internationally agreed BFD limits for handgun projectiles, with the only limits (not linked to injury) defined by the US Army Combat Helmet purchase description[6].

6.2.5 High Velocity Rifle Protection

While providing a level of rifle protection to the head has been seen as desirable for a number of years, it is only recently that materials technologies have advanced to a point where such protection is possible within physiological limits of the head and neck. However, managing the energy deposited within the helmet shell remains a significant challenge. Behind helmet blunt trauma (BHBT) caused by the impact of the deforming back face of the helmet shell on the head may still result in severe or fatal injury even if there is no penetration of the helmet shell.

A helmet that provides rifle protection must not only prevent perforation of the shell but must also limit back face deformation and manage the energy transfer to the skull. A literature review conducted by the UK concludes that the risk of human neck injury resulting from an impact from 9 mm or high velocity rifle ammunition is low[7].

The injury criteria for BHBT versus high velocity (HV) rifle threats is not yet agreed within NATO LCGDSS. AEP 2920 will be updated to include these metrics, when applicable.

6.2.6 Light and Directed Energy

With greater reliance on laser based situational awareness and targeting systems, there is a requirement to provide appropriate protection to the eyes and head borne sensors. The requirements for laser safe eyewear do not necessarily result in lenses that provide optimal photopic and scotopic high contrast, night vision, and other requirements, often leading to the provision of multiple lenses in a modular protective eyewear system. Cautious selection of wavelengths and optical density is recommended, as “over protection” will reduce visible light transmittance, resulting in low user acceptance.

An in-depth understanding of the threat and user acceptance of wavelengths/optical density will enable acceptable risks to be managed.

6.2.7 Performance Metrics

[6] CO/PD-05-04. Purchase Description, Helmet, Advanced Combat (ACH). 30/10/07.

[7] Jones, S., Hepper, A. DSTL/CR81731. Risk of Neck Injury from Ballistic Helmet Impact. 21/07/14.

In all cases, the protection afforded by a HBS can only be properly assessed if injury based performance metrics and validated test methodologies (including supporting technologies such as surrogates and other instrumentation) are available. The implementation of validated, injury criteria based test standards is an important objective.

6.3 Improve Integration (usability, compatibility, integration/systems approach)

The key elements of helmet design that design teams and industry should consider for optimised performance are sizing, usability, helmet stability, trim shape and head mounted night vision system attachment mechanism.

The key requirement for the helmet is protection from high and low velocity impacts, whilst enabling Situational Awareness (SA) and not impeding task performance. Helmet stability is a key factor to enabling these key requirements (see Section 6.5.1).

The helmet has to integrate with other systems on the torso sub-system, audio systems and weapon systems.

It is recommended that for future identification of helmet integration issues and requirements generation, the following approach should be followed:

- Engage a human factors (HF)/HF integration/ergonomist specialist;
- A systems engineering approach is used to ensure balance between SA, task performance and protection is optimised, and that emergent risk at system boundaries are managed appropriately;
- Designers of PPE should consider the physical characteristics of the DCC Soldier when designing, manufacturing and assessing equipment;
- Equipment procurement teams support the development of improved modelling and trialling, anthropometry and user assessment.

It is further recommended that the helmet be optimised for integration with interfacing equipment through design decisions and trade-offs with interfacing equipment systems using a systems engineering approach. Suitable requirements in the System Requirement Documents (SRDs) for the following design considerations should be addressed as follows:

- Movement of the helmet on the head should be minimised;
- The shape of the helmet trim should be controlled, with consideration of the protection/coverage requirement, integration with weapon-mounted sights and load carriage equipment;
- The helmet mounting mechanism should maintain the stability of the helmet.

6.4 Improved Situational Awareness

Situational awareness is critical for operational effectiveness and also plays an important role in survivability. As the head is the centre of all senses except touch, the addition of any equipment on or around the head and neck can result in significant degradation of situational awareness if not properly implemented. Equally, technology can be applied to enhance the senses of sight and hearing, or at the very least reconstruct or restore a loss in situational awareness that results from the implementation of other functionality of a HBS. In the case of hearing, a 3D surround sound display may compensate for losses associated with partial or complete helmet shell coverage over the ears.

At a minimum, the implementation of the HBS should provide minimal or no degradation to visual acuity and field of view, nor should it significantly impact speech, sound localization or thresholds of hearing.

Enhanced perception, as provided by night vision goggles for example, is extremely desirable in order to address limitations in human senses under certain operating conditions. Other desirable enhancements include adaptive lighting conditions for displays, 3D audio for radio communication (to assist in localization of friendly units) and wide base depth perception. In general, enhancement does not only improve perception as such, but employs the full capability of the senses to manage information work-load. Data displays using appropriate NATO symbology to adaptively display complex information from multiple sources can significantly improve situational awareness while imposing minimal burden on the Soldier – although cognitive burden may be increased. A useful example is a head borne implementation of tactile display to relieve the visual burden of navigation.

6.5 Improve Ergonomics (Sizing, Comfort, Stability, Centre of Gravity, Centre of Mass, Moments of Inertia, Reduction and Distribution of Weight)

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimise human well-being and overall system performance.

Functionalities such as the integration of C4I, image intensifiers/NVGs and CBRN protection are currently integrated in (or added to) helmet systems. Helmet weight increases and moments of inertia (MoI) may become worse with these added functionalities. Additionally, the need for helmet stability increases in order to be able to use image intensifiers and/or head up displays properly. Currently available suspension systems may not be the proper solution to offset the increase in helmet weight and offer the required stability. The inherent challenge for HBS is to find quantifiable solutions and enable acceptable comfort, stability and weight distribution at the same time.

The stakeholders, namely end users, industry and research organizations should work together to pursue the above mentioned solutions in finding the proper compromise between costs and fitness for use.

6.5.1 Stability and Retention

Stability refers to limiting the relative motion of the head borne system and the wearer's head. Retention refers to ensuring the helmet remains on the head during representative activity and events. These are often measured subjectively during field trials. Users are asked to assess the stability using questionnaires which rate the HBS on a multipoint Likert scale (e.g. from completely unacceptable to completely acceptable). This is conducted under multiple operational conditions using an obstacle course or simulated dismounted operations.

The move to add ever more functionality to the HBS is driving more stringent requirements on the helmet suspension/retention systems and measures of performance, in particular integration of data and image displays which are subject to degradation in performance with even small relative motion of the HBS and the wearer's eyes. This is a significant challenge as limiting relative motion generally involves a closer fit to the head, therefore decreasing comfort.

A system that allows the Soldier to easily adjust the tightness of a harness(increasing stability when required at the expense of comfort, or conversely decreasing hardness tension when stability is not required) is one possible approach to address the compromise required. But it comes at the expense of complexity of the HBS, as well as rubbing, heat, irritation, pain and distraction to the user that may degrade operational performance. Supporting these design decisions and stringent performance requirements is a need for objective measures of stability to ensure the optimal operational performance of these systems.

Basic pull tests, involving measurement of helmet rotation resulting from an impulsive downward force on the front brim of an HBS installed on a mannequin head, are sometimes used to try to quantify the performance of the suspension/retention system for example. However existing objective measures are far from being comprehensive, representative, or precise enough to assess stability with respect to display alignment during walking/running, for example, and more work is required in this area to support evolving HBS capabilities.

The helmet is required to be stable and not rotate or shift during operational activities. There may be a shift in stability due to integration of added functionalities; image intensifiers/head up displays have to remain just in front of the eye with a small margin for movement or helmet rotation.

Two development needs are identified:

1. Suspension and harness systems have to provide the stability required;
2. Test methods to assess the required stability have to be developed.

6.5.2 Mass and Inertia

The helmet is becoming the mounting platform for many different technologies; protection, sensor, display, and other information systems. While the addition of these technologies may represent a capability enhancement to the Soldier, these additions also represent an increase in the Head Mounted Load (HML) being borne by the musculoskeletal system of the wearer. The physical burden imposed by a HBS is a combination of the mass, the offset of the centre of mass (CM) with respect to the head and spine, and the distribution of the mass of the HBS with respect to the rotational axes of the head as measured by the mass moment of inertia. Exceeding user acceptable values for any or all of these parameters can negatively affect comfort, decrease endurance and operational effectiveness, and in the worst cases lead to musculoskeletal injuries.

Experimental studies focused on combat helmet design have shown that a total HML of less than 1.5 kg is preferred[8,9]. A HML of 2.0-2.5 kg appear to be acceptable but greater than 3.0 kg is generally unacceptable in the context of dismounted operations. When driving with higher head mounted loads, breakaway mounts may wish to be considered to reduce the loading on the users' neck.

Until recently, most combat helmets were on the order of 1.3-1.7 kg for the shell and suspension/retention system alone. The addition of communications systems, ballistic eyewear and/or face shields, beacons, and helmet cover quickly increase the HML. Adding an NVG and associated mount alone can drive the HML towards an unacceptable level. From the wearer's perspective, it is not just the musculoskeletal loads that are a concern. Increased HML also results in increasing pressure points associated with the helmet suspension system, requiring some attention to the design of such systems while ensuring that the often conflicting requirement for blunt impact energy absorption and behind armour blunt trauma attenuation are maintained.

The centre of mass (as defined by STANAG 2902) of a HML should be as close as possible to, if not slightly behind, the occipital condyles. Note that the head CM is not the relevant reference location as one might first assume. As the HML increases, the position of the acceptable CM moves downward but does not change significantly from front to back. This results in a competing requirement with situational awareness and head range of motion as both generally drive a higher cut of the helmet shell, pushing the helmet system CM upwards. Adding NVG's and other systems to the upper portion of the helmet shell serve to drive the CM even higher (monocular ~250 g, binocular ~350 g). The front to back location of the CM of a bare, standard combat helmet is generally acceptable. However, adding an NVG, visor, display, facial protection and other front mounted sub-systems can offset the CM in an unacceptable manner. An approach that is used by some countries to address the challenges posed by NVGs is to move the batteries from the NVG to a pack on the back of the helmet as part of a counter balance, or simply to add a counter balancing mass (~250 g). The potentially increased overall HML is deemed to be offset by the improvement in balance and reduced neck strain associated with rotational movement of the head.

Mass moment of inertia (see STANAG 2902) of the HBS is relevant to the rotational forces required to move the head. Acceptable values are related to head borne system mass but measuring preferred mass moment of inertia has proven to be challenging and more work is required in this area.

Neck pain, along with back pain, is a commonly reported complaint and can lead to musculoskeletal

[8] Maximum Helmet Weight – A Literature Review for the Dismounted Close Combat Domain. DSTL/TR52274 v1.0. May 2011.
[9] Estep. P.N., et al. Mass Properties Comparison of Dismounted and Ground-Mounted Head-Supported Mass Configurations to Existing Performance and Acute Injury Risk Guidelines. Military Medicine, 184, 3/4:245, 2019.

disorders (MSDs). Neck pain related MSDs can be correlated with the use of helmets for professions such as Soldiers, military air crew etc[10]. The neck pain related MSDs can be expected to increase with added mass and larger moments of inertia due to added functionalities. Even more, the Soldier suffers already from a mass overload endangering health and sometimes operational effectiveness.

Mass and inertia were commonly assessed during trials through user questionnaires. These methods may have been sufficient for the current helmet systems. Today, the trend is to integrate more functions into the helmet system. This increases mass and moments of inertia (MoI) considerably. The resulting mass and MoI may become too high to be bearable and may thus introduce more MSDs. There is not sufficient data proving allowable mass and MoI, as well as related methods and tools in order to prevent the aforementioned MSDs. This issue is a challenge to be dealt with in the near future. There is an evident need for more useful test methods and related requirements in this field.

6.5.3 Sizing

Today's helmet suspension systems mostly offer the possibility to accommodate a certain percentage of users in a range from three to four helmet sizes. The inherent choice is made to accommodate a certain range of head circumference, despite head length and breadth being a more appropriate measurement. This choice is insufficient for helmets becoming a platform for other systems that will be integrated in the near future. The requirement for more stability will introduce the need for suspension systems that also adjust for head length and head width. The revision of nations' anthropometry and helmet sizing using traditional measuring and 3D scanning techniques in combination with rapid prototyping have allowed a wider range of helmet sizes or made to size to become available. NATO HFM-RTG-266 (3D Scanning for Clothing and Logistics) will investigate 3D scan and fit technologies to better fit the helmet to the soldier to improve protection, mobility and survivability.

6.5.4 Comfort

A helmet can be made very stable by tightening all adjustments very tight. The problem is that this is only wearable for a short time. On the other hand, a loose helmet may not offer the required stability or protection. A compromise has to be found allowing for enough comfort and stability at the same moment.

As a subjective measure of the HBS, comfort can be a somewhat abstract component of the functional design. Related to a combination of HBS mass, location of the centre of mass, moment of inertia, presence of pressure points, airflow and thermal/moisture, and stability, it is difficult to incorporate technical requirements to address comfort into a HBS design. However, for a component of the Soldier System that can be worn for 10-12 hours or more at a time, comfort is a critical component of design that impacts operational effectiveness and that generates conflicting design drivers; particularly with respect to the protective characteristics and stability of a HBS. Iterative design with a strong component of human factors engineering complimented by extensive user evaluations are required to progress a HBS design in order to ensure an appropriate level of user acceptability.

6.6 Modular, Scalable, and Tailorable

- **Modular** - made up of separate modules that can be rearranged, replaced, combined, or interchanged easily;

- **Scalable** - describes protection levels that can be upgraded or downgraded to meet the needs of the commander based on threat;

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[10] MHAH van den Oord 2012, Thesis, *Prevention of Flight-Related Neck Pain in Military Aircrew*.

- **Tailorable** - the ability to adapt helmets to make them suitable for a particular reason (duty position, mission, threat, etc.).

The HBS will provide the Soldier multiple levels of protection that can be tailored to select mission profiles and protection against environmental noise, and specific threats from conventional fragmenting munitions, small arms ammunition, blunt impact and flame threats. Soldiers equipped with the HBS will be able to accomplish a broad range of missions. The concept and intent of providing the Soldier a modular, scalable and tailorable Soldier protection system is to speed transition between missions. The modularity and ease of configuration, and the ability to add or remove components to scale up or down protective levels allows commanders to adjust their Soldier's protection levels when transitioning between low, medium, and high threat missions. Some missions may require a trade-off of some protection components for the benefit of speed and agility. The result will be Soldiers capable of improving current expected battle outcome.

7. DIFFERENCES IN REQUIREMENTS BETWEEN NATIONS

During a series of workshops, nine nations (US, UK, NO, GE, NL, SP, CA, AS, AUS) studied the variation in requirements and concluded that requirements could be split into a large body of recognised common requirements (with agreement on rated importance), and a smaller number of requirements that may vary. The Table 2 identifies the topics involved. The origin of this list is the Battlefield Threats and Hazards To The Dismounted Soldier System report[11].

The variance is mainly caused by two factors: the climate and operational area, and the uncertainty of the best Soldier System configuration (with emphasis on the visual display system).

Table 2 - Table I Requirements, rated as common between nations and varying over nations (numbers refer to Table 4)

Requirement category	Common Requirement	Varying
Protection	1.1.1 (Ballistic/Frag) Penetration resistance 1.1.2 (Ballistic/Frag) Behind armour blunt trauma mitigation 1.2.1 (CBRN) Respiratory protection 1.2.2 (CBRN) Dermal protection 1.3.1 (Blast) Primary (overpressure) 1.5.1 (Noise) Impulse 1.5.2 (Noise) Other excessive noise 1.6.1 (Radiation) Thermal 1.11.1 (Edged weapons) Stab 1.11.2 (Edged weapons) Slash	1.2.3 (CBRN) Nuclear flash 1.4.1 (Light) Directed energy (Laser) 1.4.2 (Light) UV 1.6.2 (Radiation) Electro-magnetic 1.7.1 (Flame) Flame resistance 1.7.2 (Flame) Thermal injury 1.8 (Environment) 1.9 (Low energy impact) 1.10 (Insects) 1.12.1 (Infection) Mould and fungus 1.12.2 (Infection) Bacterial 1.12.3 (Infection) Skin irritation
Platform	2.1.1 (Optical sensors) Image intensifiers 2.1.2 (Optical sensors) Thermal imager 2.1.3 (Optical sensors) Mounts and connectivity 2.3.1 (Audio display) Microphone 2.3.2 (Audio display) Earphone 2.3.3 (Audio display) Enhanced hearing 2.3.4 (Audio display) Mounts and connectivity 2.4 (Haptic displays) 2.5.1 (Antennae) Radio 2.5.2 (Antennae) GPS 2.5.3 (Antennae) Mounts and connectivity 2.6 (Eye correction) 2.8 (Bio sensors) 2.9 (Combat ID) 2.11.1 (Power and data) Network 2.11.2 (Power and data) Power 2.11.3 (Power and data) Connectors 2.12.1 (Interfaces) Button 2.12.3 (Interfaces) Mounts and connectivity	2.2.1 (Visual display) Helmet mounted displays 2.2.2 (Visual display) Weapon mounted displays 2.2.4 (Visual display) Display mounts and connectivity 2.2.5 (Visual display) Level of detail 2.2.6 (Visual display) Display symbology 2.7.1 (SigMan) Noise 2.7.2 (SigMan) Reflectivity 2.7.3 (SigMan) Near IR 2.7.4 (SigMan) Thermal 2.7.5 (SigMan) EM 2.10.1 (Environmental sensors) Chem/bio threat sensor 2.12.2 (Interfaces) Voice activated

[11] NAAG, LCGDSS. AC/225(DSS)D(2014)0002 (PFP). 10/02/14.

Requirement category	**Common Requirement**	**Varying**
Ergonomics	3.1.1 (Fit/adjustability) Fit 3.1.2 (Fit/adjustability) Comfort 3.1.3 (Fit/adjustability) Stability 3.2.1 (Weight) Mass 3.2.2 (Weight) Balance 3.3 (Mobility) 3.4.1 (Respiration) Inhalation/exhalation resistance 3.4.2 (Respiration) CO_2 3.5.1 (Heat and moisture management) Heat 3.5.2 (Heat and moisture management) Moisture 3.5.3 (Heat and moisture management) Fogging	3.6.1 (Situational awareness) Field of view 3.6.2 (Situational awareness) Hearing 3.6.3 (Situational awareness) Speech 3.7 (Use) Cognitive burden 3.8.1 (Use) Speed 3.8.2 (Use) Operation 3.8.3 (Use) Usability 3.9.1 (Sustenance) Nutrition 3.9.2 (Sustenance) Hydration 3.10 (Vomit and saliva) 3.11 (Personal identification) 3.12.1 (Other) Smoking and related activities
Operational	4.1.2 (Time on task) Battery life 4.2.5 (Compatibility) Gloves 4.3.1 (EM effects) Anti-jamming 4.3.2 (EM effects) Interference 4.4.1 (Readiness) Battlefield hardening 4.4.2 (Readiness) Graceful degradation 4.4.3 (Readiness) Maintenance 4.4.5 (Readiness) Storage 4.5.2 (Environmental resistance) Weather resistant 4.8.1 (Compatibility) Soldier System 4.8.2 (Compatibility) Vehicle mounted systems 4.8.3 (Compatibility) Seaworthiness 4.8.4 (Compatibility) Airworthiness	4.1.1 (Time on task) Tolerance 4.2.1 (Compatibility) Clothing 4.2.2 (Compatibility) Load carriage 4.2.3 (Compatibility) Weapon 4.2.4 (Compatibility) Handset 4.2.6 (Compatibility) CBRN equipment 4.2.7 (Compatibility) Displays (not worn on helmet) 4.2.8 (Compatibility) Power 4.2.9 (Compatibility) Data 4.4.4 (Readiness) Repair 4.4.6 (Readiness) End of life of type 4.4.7 (Readiness) Decontamination 4.5.1 (Environmental resistance) Water absorption 4.5.3 (Environmental resistance) Oil 4.5.4 (Environmental resistance) Solvents 4.5.5 (Environmental resistance) Salt water 4.5.6 (Environmental resistance) Waste 4.6 Training 4.7 (Cost)

8. PRIORITISATION OF REQUIREMENTS ON HBS AND RESPONSIBILITIES

8.1 Recommended Prioritisation Scheme for Interoperability

The following section aims to identify common prioritised requirements across NATO for the standardisation of head borne systems and system component requirements in order to mitigate risks emerging from co-operative operations with allies. Note that these risks should also be considered for cooperation between national units if equipment is not harmonised across those units.

The following prioritisation scheme (Table 3) has been used for the classification of HBS requirements:

Table 3 - Prioritisation Scheme for HBS Interoperability Requirements

Priority	Desired Interoperability	Risk
1	NATO interoperability requirements for co-operation at squad level (NATO AAP-6 Compatibility and Interoperability)	Mission ineffective or loss of life because of incompatibility of HBS.
2	Minimal NATO interoperability requirement for equipment exchange (NATO AAP-6 Interchangeability, without demand for same requirements)	Mission ineffective or loss of life because inability to exchange of HBS or components.
3	National responsibility (Not classified in NATO AAP-6, may create reluctance to exchange equipment)	Nation specific requirements/functionality. Or, no impact on co-operative short-term operations.

8.2 Interoperability Requirements Priority Matrix

The requirements on head borne systems are classified with respect to priority in Table 4. This table was populated during a workshop session in 2015 (Version 1) and revised in 2022 (Version 1.1).

Table 4 - Interoperability Priorities for Head Borne Systems Requirements (Priorities 1 and 2 relate to NATO responsibilities, while Priority 3 relate to national responsibilities)

General Requirement	Specific Requirement	1	2	3
Protection Requirements				
1.1 Ballistic / Fragment Impact	1.1.1 Penetration resistance	X		
	1.1.2 Behind armour blunt trauma mitigation	X		
1.2 CBRN	1.2.1 Respiration		X	
	1.2.2 Dermal protection		X	
	1.2.3 Nuclear flash			X
1.3 Blast	1.3.1 Primary (overpressure)		X	
1.4 Light	1.4.1 Directed Energy (Laser)	X		
	1.4.2 UV			X
1.5 Noise	1.5.1 Impulsive	X		

	1.5.2 Other excessive noise		X	
1.6 Radiation	1.6.1 Thermal			X
	1.6.2 Electro-magnetic			X
1.7 Flame	1.7.1 Flame Resistant	X		
	1.7.2 Thermal injury			X
1.8 Environment				X
1.9 Low Energy Impact		X		
1.10 Insects				X
1.11 Edged weapons	1.11.1 Stab			X
	1.11.2 Slash			X
1.12 Infection	1.12.1 Mold and fungus			X
	1.12.2 Bacteria			X
	1.12.3 Skin Irritation			X
Non-protective functions				
2.1 Optical Sensors	2.1.1 Image intensifier	X		
	2.1.2 Thermal imager		X	
	2.1.3 Mounts and connectivity	X		
2.2 Visual Display	2.2.1 Helmet mounted		X	
	2.2.2 Weapon mounted			X
	2.2.4 Mounts and connectivity	X		
	2.2.5 Level of detail	X		
	2.2.6 Display symbology	X		
2.3 Audio	2.3.1 Microphone	X		
	2.3.2 Earphone	X		
	2.3.3 Enhanced hearing	X		
	2.3.4 Mounts and connectivity	X		
2.4 Haptic Feedback				X
2.5 Antennae	2.5.1 Radio			X
	2.5.2 GPS		X	
	2.5.3 Mounts and connectivity			X
2.6 Eye Correction				X
2.7 Signature Management	2.7.1 Noise	X		
	2.7.2 Reflectivity	X		
	2.7.3 Near IR	X		
	2.7.4 Thermal	X		
	2.7.5 EM	X		
2.8 Biosensors				X
2.9 Combat ID		X		
2.10 Environmental Sensors	2.10.1 Chem / Bio threat sensor		X	
2.11 Power / Data Transmission	2.11.1 Network	X		
	2.11.2 Power	X		
	2.11.3 Connectors	X		
2.12 Interfaces	2.12.1 Buttons		X	

	2.12.2 Voice activated		X	
	2.12.3 Mounts and connectivity		X	
Ergonomics Requirements				
3.1 Fit / Adjustability	3.1.1 Comfort		X	
	3.1.2 Sizing		X	
	3.1.3 Stability		X	
3.2 Weight	3.2.1 Mass		X	
	3.2.2 Balance		X	
3.3 Mobility				X*
3.4 Respiration	3.4.1 In / exhalation resistance			X
	3.4.2 CO_2			X
3.5 Heat and Moisture Management	3.5.1 Heat			X
	3.5.2 Moisture			X
	3.5.3 Fogging			X
3.6 Situational Awareness	3.6.1 Field of view		X	
	3.6.2 Hearing (localisation, attenuation)		X	
	3.6.3 Speech		X	
3.7 Cognitive Burden				X
3.8 Use	3.8.1 Speed			X
	3.8.2 Operation			X
	3.8.3 Usability			X
3.9 Sustenance	3.9.1 Nutrition			X
	3.9.2 Hydration			X
3.10 Vomit and Saliva				X
3.11 Personal Identification				X
3.12 Other	3.12.1 Smoking and all related or similar activities.			X
Operational Requirements				
4.1 Time on Task	4.1.1 Tolerance			X
	4.1.2 Battery			X
4.2 Compatibility	4.2.1 Clothing		X	
	4.2.2 Load carriage		X	
	4.2.3 Weapon		X	
	4.2.4 Handset		X	
	4.2.5 Gloves		X	
	4.2.6 CBRN equipment		X	
	4.2.7 Displays (not worn on the helmet)			X
	4.2.8 Power		X	
	4.2.9 Data		X	
4.3 EM Effects	4.3.1 Anti-jamming			X

	4.3.2 Interference		X	
4.4 Readiness	4.4.1 Battlefield hardening			X
	4.4.2 Graceful degradation			X
	4.4.3 Maintenance			X
	4.4.4 Repair			X
	4.4.5 Storage		X	
	4.4.6 End life of type		X	
	4.4.7 Decontamination			X
4.5 Environmental Resistance	4.5.1.Water absorption			X
	4.5.2 Weather resistant			X
	4.5.3 Oil			X
	4.5.4 Solvents			X
	4.5.5 Salt water			X
	4.5.6 Waste			X
4.6 Training			X	
4.7 Cost				X
4.8 Compatibility	4.8.1 Soldier System		X	
	4.8.2 Vehicle mounted systems		X	
	4.8.3 Seaworthiness		X	
	4.8.4 Airworthiness		X	

Notes:
* Mobility cannot be accurately assessed

8.3 Focus Areas for NATO HBS Interoperability

Table 5organises the requirements from Table 2by priority, highlighting the focus of work that is required within NATO in order to mitigate operational risks associated with interoperability of head borne systems.

Table 5 - Prioritised focus areas

Priority 1: Mission ineffective or loss of life because of incompatibility of HBS	1.1.1 Penetration resistance (ballistic / fragment impact)	2.3.3 Enhanced hearing (audio display)
	1.1.2 BABT mitigation (ballistic / fragment impact)	2.3.4 Mounts and connectivity (audio)
	1.4.1 Directed energy (laser)	2.7.1 Noise (signature management)
	1.5.1 Impulsive (noise)	2.7.2 Reflectivity (signature management)
	1.7.1 Flame resistant (flame)	2.7.3 Near IR (signature management)
	1.9 Low energy impact	2.7.4 Thermal (signature management)
	2.1.1 Image intensifier (optical sensors)	2.7.5 EM (signature management)
	2.1.3 Mounts and connectivity (optical sensors)	2.9 Combat ID
	2.2.4 Mounts and connectivity (visual display)	2.11.1 Network (power / data transmission)
	2.2.5 Level of detail (visual display)	2.11.2 Power (power / data transmission)
	2.2.6 Display symbology (visual	2.11.3 Connectors (power / data

	display)	transmission)
	2.3.1 Microphone (audio display)	
	2.3.2 Earphone (audio display)	
Priority 2: Mission ineffective or loss of life because inability to exchange a HBS or components	1.2.1 Respiratory protection (CBRN)	4.2.2 Load carriage (compatibility)
	1.2.2 Dermal protection (CBRN)	4.2.3 Weapon (compatibility)
	1.3.1 Primary (overpressure)	4.2.4 Handset (compatibility)
	1.5.2 Other excessive noise (noise)	4.2.5 Gloves (compatibility)
	2.1.2 Thermal imager (optical sensors)	4.2.6 CBRN equipment (compatibility)
	2.2.1 Helmet mounted (visual display)	4.2.8 Power (compatibility)
	2.5.2 GPS (antennae)	4.2.9 Data (compatibility)
	2.10.1 Chem / bio threat sensors (environmental sensors)	4.3.2 Interference (compatibility)
	2.12.1 Buttons (interfaces)	4.4.5 Storage (readiness)
	2.12.2 Voice activated (interfaces)	4.4.6 End of life type (readiness)
	2.12.3 Mounts and connectivity (interfaces)	4.6 Training
	3.1.1 Comfort (fit / adjustability)	4.8.1 Soldier System (compatibility)
	3.1.2 Sizing (fit / adjustability)	4.8.2 vehicle mounted systems (compatibility)
	3.1.3 Stability	4.8.3 Seaworthiness (compatibility)
	3.2.1 Mass (weight)	4.8.4 Airworthiness (compatibility)
	3.2.2 Balance (weight)	
	3.6.1 Field of view (situational awareness)	
	3.6.2 Hearing (situational awareness)	
	3.6.3 Speech (situational awareness)	
	4.2.1 Clothing (compatibility)	
Priority 3: Nation specific requirements/functionality. No impact on co-operative operations.	1.2.3 Nuclear flash (CBRN)	3.5.1 Heat (heat and moisture management)
	1.4.2 UV (light)	3.5.2 Moisture (heat and moisture management)
	1.6.1 Thermal (radiation)	3.5.3 Fogging (heat and moisture management)
	1.6.2 Electro-magnetic (radiation)	3.7 Cognitive burden
	1.7.2 Thermal injury (flame)	3.8.1 Speed (use)
	1.8 Environment	3.8.2 Operation (use)
	1.10 Insects	3.8.3 Usability (use)
	1.11.1 Stab (edged weapons)	3.9.1 Nutrition (sustenance)
	1.11.2 Slash (edged weapons)	3.9.2 Hydration (sustenance)
	1.12.1 Mould and fungus (infection)	3.10 Vomit and saliva
	1.12.2 Bacteria (infection)	3.11 Personal identification
	1.12.3 Skin irritation (infection)	3.12.1 Smoking and all related similar activities (other)
	2.2.2 Weapon mounted (visual display)	4.1.1 Tolerance (time on task)
	2.4 Haptic display	4.1.2 Battery (time on task)
	2.5.1 Radio (antennae)	4.2.7 Displays (not worn on the helmet)
	2.5.3 Mounts and connectivity (antennae)	4.3.1 Anti-jamming
	2.6 Eye correction	4.4.1 Battlefield hardening (readiness)
	2.8 Biosensors	4.4.2 Graceful degradation (readiness)

	3.3 Mobility	4.4.3 Maintenance (readiness)
	3.4.1 In / exhalation resistance (respiration)	4.4.4 Repair (readiness)
	3.4.2 CO_2 (resistance)	4.4.7 Decontamination (readiness)
		4.5.1 Water absorption (environmental resistance)
		4.5.2 Weather resistance (environmental resistance)
		4.5.3 Oil (environmental resistance)
		4.5.4 Solvents (environmental resistance)
		4.5.5 Salt water (environmental resistance)
		4.5.6 Waste (environmental resistance)
		4.7 Cost

9. INTEROPERABILITY ISSUES DISCUSSED

Sections 9.1 discusses in more detail the standardisation of HBS requirements that have been identified (in Table I) to impact mission effectiveness and/or Soldier survivability if there is a lack of interoperability across NATO nations (Priority 1 and Priority 2 requirements).

Section 9.2 lists specific HBS requirements that were deemed to be nation specific with no impact on co-operative operations (Priority III requirements).

9.1 Requirements for Full HBS Compatibility

9.1.1 Protection Requirements

Requirement **1.1.1 (Ballistic / Fragmentation) Penetration Resistance -** Whilst NATO nations will be using common standards for the assessment of ballistic threats, such as AEP 2920, there may be a requirement that necessitates the use of NATO ally ballistic protection (HBS). Knowing the specification of that system is key to identifying whether that helmet provides a minimum level of protection.

Requirement **1.1.2 (Ballistic / Fragmentation) Behind Armour Blunt Trauma Resistance** – Unlike ballistic protection for the torso, there are no NATO BABT standard for HBS, with nations selecting available methods and injury criteria that may or may not be representative of the threat faced, or even the correct threat. STANAG 2902 Criteria for NATO Combat Helmet Edition 2 is the closest to specifying a NATO helmet, but does not presently recommend a BABT test or injury criteria for ballistic threats.

Requirement **1.2.1 (CBRN) Respiratory Protection –** NATO AEP-73 Edition B, Version 1 (June 2021) sets a minimum standard for nations respirator protective equipment in order to enhance interoperability between NATO forces. This standard provides operational requirements, technical specifications, test methodology and acceptance criteria to be applied during the acquisition and through-life management of CBRN respirators.

Requirement **1.2.2 (CBRN) Dermal Protection** – NATO AEP-38 Edition B Volume 1, Version 2 and Volume 2, Version 1, sets a minimum standard for nations dermal protective equipment in order to enhance interoperability between NATO forces. This standard provides operational requirements, technical specifications, test methodologies and acceptance criteria to be applied during the acquisition and through-life management of CBRN protective clothing. The clothing system including auxiliary equipment shall be capable of protecting the skin of the whole body continuously against CBRN agents. The procedures and test equipment may need modification when testing a HBS in order to take into account the interfaces between its components.

Requirement **1.3.1 (Blast) Primary (Overpressure)** – Medical community validated and injury correlated blast over pressure requirements for HBS do not currently exist. However, blast sensors in combination with interpretation software may be used to monitor primary blast loading to the HBS.

Requirement **1.4.1 (Light) Directed Energy (Laser) -** Laser eye protection (LEP) is a vital requirement on the battlefield, not only due to enemy laser systems, but also allied lasers emitted from accidental or passive laser marking or attention seeking systems.

Standardisation should include specific wavelength(s) of interest given an identification and agreement of threat or priority wavelengths. The challenges faced with this include security classification; as such threat assessments are usually highly classified and held at national level.

In cooperative operations there is a need for all Soldiers to be protected from allied laser systems in use, as well as adversary laser systems that are considered a likely threat. Nations must therefore share laser specifications for their own systems to ensure that each participating nation has adequate laser eye protection. If intelligence of adversary laser system specifications are not shared, each nation must independently assess the risks and protect their Soldiers accordingly.

Given a set of laser specifications, the risk of laser eye damage and the protection level required can be calculated according to existing international standards (e.g. STANAG 4495, STANAG 3606, EN 60825, ANSI Z136).

There is no standardised advice to mitigate the risks of laser eye dazzle; the most commonly encountered issue with adversary laser systems. Therefore, even if each nation possessed the same intelligence of adversary laser systems, they may provide their own Soldiers with different protection levels based upon their own understanding of laser eye dazzle effects.

To address interoperability there needs to be a standardised procedure for nations to share specifications of their laser systems with allies. For systems with classification sensitivities this may involve providing protection levels (wavelength and optical density) rather than the laser specifications themselves. This could also involve providing laser eye protection solutions to other nations, but physical integration with other equipment may prevent this from being practical. Laser eye dazzle effects need to be described and quantified in standards so that all nations can specify adequate protection from the laser eye dazzle threat.

Establishing a standardised method of laser specification sharing for cooperative operations should be straightforward. Enforcing the sharing of specifications may be harder to achieve due to classification issues. Standardisation of laser eye dazzle effects is being investigated by NATO SET-249.

A revised STANAG 4495 is currently undergoing the ratification process under the new title of "GUIDANCE FOR THE PROCUREMENT OF LASER EYE PROTECTION (LEP) FOR THE INDIVIDUAL MILITARY USER". This new document serves as a check list for nations procuring laser eye protection to ensure that they account for all relevant factors when writing a specification (e.g. physical requirements, optical properties, quality and robustness) in addition to the basic requirements of laser protection. The approach of specifying wavelengths of interest and required protection levels was specifically avoided as the rapidly evolving nature of laser sources would quickly render any advice inaccurate, and also several nations would not wish to share such information due to classification sensitivities. However, the document gives guidance for assessing the wavelengths of interest and the protection levels needed. A NATO SET technical group (SET-198 'Visible Laser Dazzle – Effects and Protection') is researching the impacts of laser eye dazzle on human vision (as well as on visible camera systems). A UK and US collaboration is developing a new safety framework for laser eye dazzle that aims to standardise the calculation of laser eye dazzle effects. This would ensure that every nation has the ability to calculate the same protection levels required against specific dazzle threat laser systems. The UK and US are planning to pursue adoption of this framework across military and civilian laser safety standards.

Laser event recording and warning systems are being developed, and should be deployed in environments where laser threats exist. This serves the purpose of warning users to a laser threat -

from eye damage/dazzle but also targeting through laser range finders, and also records the laser's wavelength.

Requirement **1.5.1 (Noise) Impulse** – Excessive and continuous noise can cause permanent and disabling hearing damage. Hearing loss can be gradual resulting from exposure to noise over time, but damage can also be caused by sudden, extremely loud noises such as mortar or small arms fire.

Hearing loss is not the only problem. People may develop tinnitus (ringing, whistling, buzzing or humming in the ears), a distressing condition which can lead to disturbed sleep.

The UK define 'exposure action values' – levels of noise exposure which, if exceeded, require you to take specific action (

Table 6). There are 'lower' and 'upper' action values. However, impulse noise is quite specific for the military environment. Other countries use different injury criteria. There is a need for a NATO standard covering criteria and test methods to prevent hearing damage; methods to determine detrimental effects of hearing protection on military situational awareness in terms of operational effectiveness are also required.

Table 6 - Noise exposure action values

	Lower exposure action value (decibels)	Upper exposure action value (decibels)
Daily or weekly personal noise exposure ($L_{EP,d}$ or $L_{EP,w}$)	80	85
Peak sound pressure (L_{Cpeak})	135	137

Requirement **1.5.2 (Noise) Other Excessive Noise** – See 1.5.1.

Requirement **1.7.1 (Flame) Flame Resistance -** Flame resistance (FR) is a priority for standardisation for HBS as flame related injuries are both a life threatening and quality of life concern for militaries. Ensuring HBS systems are standardised for FR properties is key to Soldier safety within both national and interoperable roles. This includes the helmet cover, shell, and inner components such as liner/comfort pads.

Specific to HBS, FR standardisation would focus on requirements for textile based items, especially helmet covers, and 'no drip/melt' requirements for plastic and rubber components. This will ensure that any components worn with or mounted on a HBS of any nation will not provide an immediate flame injury risk.

Challenges to defining standards for these requirements include:

- Garnering consensus on which FR standard(s) to use;
- Minimum values for no drip/melt and test method;
- Varity of materials available to be used in a HBS component;
- National command resistance;
- Industry ability and desire to meet standard.

Requirement **1.9 (Low Energy Impact)** – Low energy impacts include low impact bumps to elbows, knees, etc, and is an important requirement for Soldiers' uniforms. A standardised test method is required to assess impact speed, impact location, impacted material, etc.

9.1.2 Non-Protective Requirements

Requirement **2.1.1 (Optical Sensors) Image Intensifier** – Being able to operate under low ambient light conditions is fundamental for the Dismounted Soldier. This ability is underpinned by the use of compact, head mounted night vision devices (HMNVDs) operating over visible/near infrared (NIR) wavelengths. These devices are currently dependent on analogue-based imaging techniques, relying upon Image Intensifier (II) tube technology to make low light scenes visible to the soldier. There are various configurations of HMNVDs (e.g. binocular, biocular, monocular) although the trend is towards the deployment of binocular devices.

There are, in addition, parameter options with regard to the II tube type and performance, including:

- Photocathode type:
    - Light sensitivity/signal-to-noise;
    - Spectral sensitivity;
- Spatial resolution;
- Manual/auto-gain functionality;
- In-built illumination source spectral output.

All of these have the potential to impact upon interoperability.

Moving beyond analogue (II-based) devices towards digital sensors in the future will require a coordinated adoption of technology/data & cabling standards to ensure the enhanced system performance benefits can be shared between dismounted personnel.

Developments in the presentation of augmented reality data within HMNVDs (navigation information, location of friendly/hostile forces, points of interest etc.) will continue but this is covered elsewhere in the document.

Requirement **2.1.2 (Optical Sensors) Thermal Imager -** There are an increasing number of cases of clip-on thermal imagers being used in combination with visible/NIR HMNVDs. Such thermal imaging devices provide a 'no light' imaging capability as well as enhanced people detection and recognition performance. Since these are digital camera systems operating/performance characteristics may vary between devices. These can include:

- Sensitivity (e.g. Noise Equivalent Temperature Difference, NETD);
- Spatial and temporal resolution (including collection/display rates);
- Field of View;
- Operating controls;
- Power requirements;

- Mounting bracket configuration (to host HMNVD).

Standardising these characteristics would allow clip-on thermal imagers to seamlessly augment optical HMNVDs across cooperating soldier forces.

In the longer term many NVDs are likely to have integrated thermal imagers so that interoperability issues are less likely to present themselves but a modular approach to optical/thermal imaging could persist for some time, driven by issues related to cost, flexibility and SWaP. Additionally, multiple sensor configurations involving digital imagers mounted on the helmet, to provide wider situational awareness, are being considered. Therefore, fittings, connectors and image presentation formats are all likely to need careful consideration.

Requirement **2.1.3 (Optical Sensors) Mounts and Connectivity** – As capability improvements have emerged, it is clear that a "universal helmet mount" could not have been predicted. It is desirable, but not paramount, that mounts enable connectivity to the maximum extent possible. As stated previously, nations will bring to the fight equipment that they have been issued, have trained and are familiar with.

This requirement is defined as the ability to exchange the optical sensors from one nation's HBS to another. This ability can be achieved through either the use of a universal helmet mount that is capable of accepting and stabilising the optical sensors from each nation, or through the use of a universal attachment method that allows the mounts themselves to attach to the helmets of each nation. Standardising the attachment method is likely to be more achievable than standardising the mounting system.

Customary attachment methods typically involve either a hard mounted system that bolts through the helmet shell, a strap type system that tensions across the exterior of the helmet shell, or a mount that is moulded directly into the helmet shell. Each of these attachment methods presents its own set of difficulties in adapting to multiple helmet types.

A mounting system that bolts through the helmet shell provides good stability for the optical system but presents several interoperability challenges in terms of the number of bolt holes that are needed to attach the mount, the dimensions of the bolt holes, the location of the bolt holes, as well as the thickness of the helmet shell. Additionally, the introduction of new or additional holes through the helmet shell has the potential to weaken the ballistic integrity as well as the blunt impact protection provided by the helmet shell.

A mount that is moulded directly into the helmet shell falls into the category of a universal helmet mount rather than a universal attachment method, as it will need to be able to accept and stabilise all of the optical sensors used by all of the participating nations. While this type of mount provides good stability for the optical system, it offers no adjustability and could potentially necessitate replacement of the entire helmet shell if repairs are needed to the mount or if changes are made to the optical system.

A mount that attached via a tensioning strap provides the adjustability needed to fit helmets of differing sizes and shapes, and does not necessitate any physical changes to the helmet shell. However, tensioning strap type systems have the potential to present more challenges to the stability of the optical system than hard mounted or molded systems. Additionally, decisions will still have to be made regarding the amount and location of space that the mount and tensioning strap will occupy on the helmet shell as well as minimum and maximum dimensions for the strap to accommodate the entire range of helmet sizes without adding extraneous weight and bulk.

Requirement **2.2.1 (Visual Display) Helmet Mounted** – See 2.2.4.

Requirement **2.2.4 (Visual Display) Mounts and Connectivity** – The LCG for DSS contains the C4I and Soldier Architecture Sub Group (C4ISA SG). Its principal task to date has been to draw up a STANAG to enhance C4I interoperability between dismounted Soldiers at the lowest levels of tactical command. This STANAG – 4677 – has been both ratified and promulgated and the emphasis of the Group's work has switched to commence a holistic review of Soldier architecture(s).

The requirement has been identified both from the scenarios adopted as points of reference for the LCG (contained in the document 'Soldier System Interoperability LCGDSS Overarching Definition', dated February 2017) and operational experience, i.e. as much individual Soldier equipment as possible should be interoperable, in order to prosecute Alliance operations more effectively.

The UK offered the Generic Soldier Architecture (GSA - Def Stan 23-12) as a potential starting point and this looks at the dismount's equipment in terms of helmet, torso and weapon. It formed the basis of initial discussions at the LCG meeting held in Brussels 9 – 13 Mar '15 and before that at the interim meeting, held in UK on 5 and 6 Feb '15. It is the SG's intent to:

- Identify interfaces both between and within the 3 areas of helmet, torso and weapon;
- Identify how nations are approaching the challenges of enabling the necessary interfaces. This would not only include what flows across them, i.e. power and data, but also how that is enabled – e.g. wire, wireless;
- Identify common approaches amongst nations' approaches in this regard. These are likely to include not only items identified by the Head Borne Systems TOE, i.e. (Visual Display) Mounts and Connectivity, (Visual Display) Level of Detail, (Visual Display) Display Symbology, but also items such as power supply, connectors and how these are all integrated on the Soldier – as per the UK GSA;
- Propose a way ahead, which might (TBC) be termed a NATO GSA. If this course were adopted, it would mirror what has happened with the UK Generic Vehicle Architecture, which has formed the basis of a NATO standard. The output would include suggestions for where standardisation should be pursued and why.

It is proposed to produce a STANREC, which is not as binding on nations as a STANAG.

Requirement **2.2.5 (Visual Display) Level of Detail** – See 2.2.4.

Requirement **2.2.6 (Visual Display) Display Symbology** – See 2.2.4.

Requirement 2.3.1 **(Audio) Microphone -** Microphones are required to enable the user to communicate via voice via the radio(s).

Requirement 2.3.2 **(Audio) Earphone** – Earphones permit the listening of communication via the radio/headset. This may be coupled with hearing protection.

Requirement **2.3.3 (Audio) Enhanced Hearing -** An enhanced hearing capability allows the dismounted Soldier to discern lower levels of sound than are possible with the naked ear alone. With a common understanding of sub-system performance attributes, the likely effect on mission success can be made by mission planners and an informed decision can be made on the exact nature of multi-national ORBATs.

Whilst this may be sufficient to establish the overall make up of a squad or collection of different nation squads working collaboratively and under known noise environments, the ability to share equipment, where that equipment involves the passage of information to the User via an audible process, will not be possible unless there is a common interfacing mechanism.

Specific attributes requiring standardisation therefore include, but are not limited to:

- Amplification (Gain) and Reduction (Attenuation) Factors – The factor by which sound of interest can be amplified or reduced can be via steps or as a continuum. The increments themselves need not be common but the audible signal to the User, identifying what gain state the equipment is in should be standardised (tone, number and duration). This will allow any User to quickly and accurately identify the current level of protection that he / she is being afforded;

- Alerts and Messages – Alerts and messages that include an audible component will cause confusion when utilising another nation's equipment if a standard is not adopted. Alerts and messages typical of an enhanced hearing system include; low / critical battery warning and loss of function. The method of dismissing an alert should also be standardised;

- Controls – The controls of the enhanced hearing system should be standardised if the use by another nation is required;

- Connectors – If it is intended to use the enhanced hearing equipment as a module within another nation's HBS then the controls to utile the equipment should be standardised; both in position and in type / size.

STANAG 4677 addresses the general subject of information transfer across hearing devices.

Requirement **2.3.4 (Audio) Mounts and Connectivity** – This requirement is taken as the ability of one nation's HBS to be compatible with the audio displays used by another nation as well as the possibility to connect one nation's HBS (as a complete system) to the communication system of another nation. This compatibility includes:

- The compatibility of the HBS audio display connectors with the radio system of another nation;
- The possibility of replacing the original audio display system of the HBS by the audio display of another nation.

The partial or total replacement of the original audio display must not:

- Affect the other requirements of the HBS;
- Generate any additional risk for the Soldier;
- Alter the electromagnetic capability with the HBS components and with the other components of the Soldier System.

Requirement 2.5.2 **(Antennae) GPS -** A device designed to receive and amplify the radio signals transmitted on specific frequencies by Global Navigation Satellite System (GNSS) satellites and convert them to an electronic signal for use by a GNSS or GPS receiver. The output of the GNSS or GPS antenna us utilised be a GNSS or GPS receiver that can compute the position.

Requirement **2.7.1 (Signature Management) Noise** – This requirement is for NATO to establish a noise or acoustic signature decibel range for components of the HBS and associated equipment mounted to the HBS. The noise emitted from the HBS or any HBS mounted equipment has the potential to alert adversaries to an individual's presence and/or their location.

Requirement **2.7.2 (Signature Management) Reflectivity -** The requirement is for NATO to establish a reflectivity requirement for both the HBS and associated equipment that is mounted onto the HBS. This could include using non-reflective paints with a matte type finish or other visible light absorbent materials/finishes. Therefore, different tables would need to be generated based on the method(s) that are used to combat this signature offender.

Requirement **2.7.3 (Signature Management) Near IR** - The requirement is for NATO to establish a standard range of Near Infrared (NIR) wavelengths and respective min/max percentages for their reflectance at a given wavelength(s). Minimising the reflectance percentage for a range of NIR wavelengths is critical in providing adequate signature protection from adversaries. These requirements will be used for both the HBS and associated equipment that is mounted onto the HBS.

Different tables would need to be generated based on the method(s) that are used to combat this signature offender. Methods could include (but not limited to) the use of specifically treated Chemical Agent Resistant Coating (CARC) paints, texturing agents, treated fabric based covers, etc.

Requirement **2.7.4 (Signature Management) Thermal -** The requirement is for NATO to establish a standard unit of measure and associated range to minimise the thermal signature emitted by the HBS or associated equipment that is mounted onto the HBS.

Requirement **2.7.5 (Signature Management) EM** – The requirement is for NATO to establish a standard for minimising the frequencies and field strengths of the electromagnetic signature of the HBS or associated equipment that is mounted onto the HBS. The HBS or associated equipment that is mounted to the HBS can become a signature offender if the components within the system are not adequately protected/shielded.

Requirement **2.9 (CID)** – The HBS must provide some ability to assist in Combat Identification (CID). Helmets provide a unique profile portion of the Soldier's silhouette regardless of body position e.g. standing, kneeling or prone; therefore it is a prime area for CID interrogation.

CID occurs primarily in day time through visual examination and by infra-red (IR) in night or poor visibility conditions. From the perspective of the wearer, their HBS should be able to provide distinct CID from both a visual and IR interrogation. For outgoing CID interrogation, the HBS must be able to accommodate the IR tool and interpretation of data mechanism.

CID through a HBS could be accomplished in a number of methods including:

- Helmet covers or paint IR recognition properties. Interoperability would require a NATO standard;
- Ability to mount IR devices, either for IR designators and/or IR results interpretation devices;
- Distinctive shape(s)/profile(s) unique to NATO members.

Requirement **2.10.1 (Environmental Sensors) Chem / Bio Threat Sensor** – The requirement for chem/bio sensors to be standardised is due to the common threat and technologies used for detection.

Requirement **2.11.1 (Power / Data Transmission) Network** – The requirement is for NATO to have complete compatibility between nation's HBS including the power and data functionality. It is assumed that this level of compatibility will essentially mean the same power capability (voltage level and current draw capability) and the same data format and message set. This will be more difficult to achieve than interoperability since many nations will have their own contracts and national industry may be offering a bespoke solution.

Standardisation of the entire HBS power and data architecture will make interoperability of helmet borne peripherals simpler, more efficient and more ergonomic than having to convert voltages and data formats from one nation's standard to a NATO standard and potentially then to the other nation's standard.

There are likely to be three main areas to enable interoperability of head borne peripherals between nations; physical, electrical and data. Electrical interoperability will be necessary to allow a peripheral of one nation to be powered by the helmet (or torso if interconnected) sub-system. Data interoperability will be necessary to allow data from one helmet peripheral to be shared with another peripheral or with the core Soldier data system. These areas are expanded below:

- **Physical interface -** To allow a peripheral to attach to a NATO helmet;
- **Electrical interface** - This will include the physical connector and the voltage operating range at which a NATO powered helmet operate. It will also be useful to specify a maximum current that could be supplied by the NATO helmet system. Power quality and noise etc may need to be defined but this is not expected to be an issue for essentially battery powered dc systems;
- **Data interface** - This will require as a minimum the data protocol e.g. USB 2.0, 100 Base-T Ethernet, etc to be defined and a decision made as to whether this functionality would be incorporated into the same connector as the power interface. Depending on the level of interoperability required and the data protocol selected many other things may need to be defined e.g. operating system, drivers, message formats etc. Security protocols may also need to be considered to determine which equipment's are allowed to be connected or not. A common data interface may more complex for HBS due to the potential need to manage digital video processing and the fact that for centre of mass reasons imagery is often moved from optical devices at the front of the helmet to a processor at the rear and back to displays.

All of the above areas will need to be agreed upon. The voltage level could sensibly be anywhere in the range of approximately 3 V to 48 V. Any voltage in this range will work reasonably well for a helmet system. The choice of maximum peak and continuous current will need to be reached by a consensus on the likely equipment to be connected to a HBS and the maximum predicted current draw for such equipment. Noting that 10-20 V distribution voltage has been recommended in STANAG 4695 and 4851 this could be a sensible choice it it does not impact other decisions (e.g. helmet mounted battery size). A lot of consumer electronics has adopted the USB Power Deliver protocol. This allows a peripheral to negotiate its required voltage, the current limit is set to 5 A. Version 3.0 limited the maximum voltage to 20 V but the recent version 3.1 now allows a maximum of 48 V. A higher voltage allows lower current and thinner wires for a given power. However, a higher voltage requires more battery cells in series or a dc to dc converter to step up voltage and has associated inefficiencies. The more difficult challenge will be on agreeing how to manage data on a HBS and whether a HBS will be a fully independent zone e.g. with a central power and data management hub or whether a HBS will simply move power and data between points but will ultimately be controlled by a torso central power and data manager.

The LCGDSS has produced a promulgated soldier power connector STANAG 4695 and a promulgated soldier power and data connector STANAG 4851. Both connectors are the same with different but coherent assignments of the 6 pins. These use USB 2 as the data protocol and both a 5 V USB power line and an additional 10-20 V, 5A higher power line on the power connector. These may not be the optimum connectors for a helmet borne system but should be investigated as some of the logic for interoperability will be relevant. Such connectors may be suitable for connection of the torso to the HBS or perhaps from the torso to the HBS via a break-away interface. STANAG 4677 is the C4 interoperability STANAG and has currently referenced the STANAG 4851 connector this may or may not impact choices for the Helmet system.

LCGDSS has also drafted a NATO Generic Soldier System Reference Architecture, STANREC 4845. This has recommended USB 3 as a future data format and USB power delivery for power transfer. It has yet to recommend a connector since a suitably rugged and open source connector was not available when the document was written.

The UK has written a Generic Soldier Architecture Defence Standard 23-12 although in the current version there are limited details only on a helmet system. The UK has plans to more fully populate the helmet section in later versions. NATO LCG is beginning to investigate a NATO GSA. This will need to be compatible with HBS.

Requirement **2.11.2 (Power / Data Transmission) Power** – See 2.11.3 Connectors.

Requirement **2.11.3 (Power / Data Transmission) Connectors** – This requirement is taken as the ability to completely exchange a HBS or to exchange peripherals from one nation's HBS to another.

The ability to completely exchange a HBS will depend on whether it is connected via a tether or wirelessly to the torso or weapon system. If the HBS is an enclosed system with no connections (wired or wireless) to the torso or weapon then the ability to exchange between nations has no power and data requirement but will depend on the ability to swap helmets and the legal requirement for protection afforded by the helmet of different nations.

If the HBS does have a wired connection to the torso system there would need to be an appropriate connector (and possibly adaptor) to allow it to be connected to the torso of another nation within minimal snag hazard and optimised ergonomics. It would also need to be ensured that the correct electrical specifications were present (e.g. voltage and current) to allow safe operation of the system attached to different torso systems. The data formats, message sets and drivers etc. would also need to be present to allow the HBS of one nation to operate when attached to the torso system of another nation.

There is unlikely to be wireless transfer of power from the torso to the HBS in the near future, but if this was the case then NATO would need to define a common protocol to achieve this. Commercially the Chi protocol for wireless charging has gathered some acceptance.

If wireless transfer of data is required then a common protocol and message set to allow this to happen would need to be defined. Bluetooth and Wi-Fi protocols are possible as well as bespoke solutions, but the major issue may be agreeing security protocols.

It is perhaps more likely that standardisation would allow the exchange of HBS components e.g. sharing of NVGs, eye displays, etc. between nations.

To enable standardisation the peripherals would need to have a common connector, or be able to adapt to a common NATO connector, and operate in a defined voltage range within a given current limit. Data protocols, and message sets would need to be defined to allow data to be transferred.

The exchange of HBS components is likely to be the more realistic requirement and will be more achievable in the near term.

To enable power and data to be exchanged between peripherals of one nation and the HBS of another the voltage range, available electrical current limits and data protocol and message sets will need to be defined. A physical connector with allocated pin assignment will need to be defined.

For a HBS, ergonomics is a very important factor. How equipment may connect to a HBS could significantly affect this. What may be appropriate for a body worn system may not be appropriate for a helmet. There are two general types of connectors which could be used on a HBS. Cylindrical (or barrel) connectors are the most common and align well with traditional cable runs. They may be an appropriate solution if the HBS is provided by running cables around the helmet; however this can add mass and become a snag hazard. A more ergonomic approach would be to enable the HBS by embedding the power and data network either into the helmet structure, or perhaps by using flat conductors such as smart textiles closely wrapped around the helmet of embedded into a helmet cover. To make best use of such flat systems a flat or low profile connector is required. A number of connector companies are developing such low profile connectors. However currently there is no open or multiple source connector suitable for Soldier Systems and this will present an issue for NATO standardisation.

Technically moving power around the HBS is relatively simple and the only challenge will be in NATO selecting an appropriate current and voltage limit for the interface which can be agreed upon by most partners.

The choice of data format will very much depend on the ambitions of each host nation as to how much functionality they envision from a HBS. High definition video and low lag applications may require one data format but command a Size Weight and Power (SWaP) penalty whereas other nations may want a less capable system with a low SWaP premium. It will always be possible to build adaptor circuits to convert the voltage, current and data format of one nation’s to another but such adaptor circuits will have their own SWaP penalties and may not be practical on a HBS. However, even adapters are challenging without any NATO standards since there could be many different types of connectors for different nations.

UK MWPD TDP2 has demonstrated a flat connector. US SPIRIT system has demonstrated a different flat connector.

Requirement **2.12.1 (Interfaces) Buttons** – Interface buttons incorporated in a HBS are a priority for standardisation as they play a critical part in a Soldier’s ability to effectively utilise the equipment. If a Soldier is unable to easily discern the purpose of a button, especially in darkness or due to encumbrance of equipment, there are a multitude of negative effects that can occur.

Likewise, from an interoperability perspective, buttons require a level of commonality of identification as to their purpose.

For buttons there are two elements that need to be examined for standardisation; first, the ability to discern a button's purpose by tactile means and second, the positioning, size, spacing and colour of buttons based on commonly defined purpose. For the first element, identifying purpose exclusively through tactile means, can be done through shape and/or raised or indented markings on the button. For the second element position, size and spacing minimums need to be defined and standardised. This will help to ensure that the identification marking has sufficient landscape to be registered via tactile means without confusion or overlap while allowing prompt operation of the button. This could include defining common positioning of key buttons such as on/off, illumination or volume.

Challenges to defining standards for these requirements include:

- Garnering consensus on what defines key buttons requiring standardisation;
- Minimum number of buttons on a device to fall under the standard;
- Defining common shape and markings for defined buttons;
- Landscape availability on smaller devices;
- Industry push back against common button design.

There are no known reference standards currently existing, but is should also be noted that buttons are not always necessary, wheels and other input devices may be more intuitive or appropriate.

Requirement **2.12.2 (Interfaces) Voice Activated** – The standardisation of voice activation of any equipment is considered to be limited to relatively few parameters:

1. Language. Software complexity will be greatly reduced if a common language is chosen. This is to be English (UK).

2. Offline or online data handling. COTS solutions vary in their use of on or off-line data handlers. Those systems that employ on-line data handling of inputted voice data rely on reliable data transfer between the transmitter and receiver of any system. For instance, a system using a central server to handle all data that is sent wirelessly must be able to communicate with its user equipment if it is to be a reliable system. In a military setting the communications capability is often not suitable for this type of system and so standardisation should be based on off-line handling of voice data.

3. Vocabulary. The requirement to handle data offline sets limits on the intelligence of the system. For instance, if an on-line server were used it could be housed in a large, climate controlled facility with any amount of power. A system housed entirely within the equipment itself will have power and space limitations and therefore will be limited in its ability to handle the entire vocabulary and all colloquial use of English. A common vocabulary will therefore be required.

Requirement **2.12.3 (Interfaces) Mounts and Connectivity** – The Universal Mounting Shroud (UMS) is positioned at the front centre of the combat Helmet. It is to be used for mounting night vision equipment but can be used for any accessory that needs to be positioned on the front of the combat Helmet.

Picatinny rails mounted on the Helmet will provide one of the physical interfaces for Helmet role equipment, in accordance with NATO STANAG 4694. The development of open/non-proprietary power and data enabled rails will enable nations to avoid vendor lock-in and sole helmet suppliers.

9.1.3 Ergonomic Requirements

Requirement 3.1.1 **(Fit / Adjustment) Comfort -** The physical comfort, or discomfort, of the helmet is affected by a number of factors related to the HBS; retention system, suspension system, fit, stability, mass, CoM, and position of the helmet. It is also affected by history, emotional state, aesthetics, duration of wear, and overall user acceptance. Discomfort can cause headaches, lead to distraction, affect user acceptance and ultimately affect cognitive and physical performance.

Requirement 3.1.2 **(Fit / Adjustment) Sizing -** Anthropometric measurements of the head are required to assign helmet sizes to users based on the manufacturer's sizing criteria, to then assess if the sizing of the helmet range is appropriate for the population and to identify where problems relating to fit or discomfort may exist. The head measures relate to the sizing and fit of both the helmet shell/suspension system as well as the retention system/chin strap.

Requirement **3.1.3 (Fit / Adjustment) Stability** – Stability of the HBS is very important to ensure that the user is capable of performing their mission. The HBS design must ensure that the protective helmet provides and maintains adequate coverage and proper positioning on the head. Stability is a function of a helmet's fit (shape/sizing structure) in addition to the suspension and retention system used in the design. This includes keeping the helmet in the proper "as worn" condition throughout operational use (including but not limited to activities like running, jumping, prone shooting, and airborne free-fall) with and without enablers/attachments (e.g., Night Vision Devices (NVD) and maxillofacial systems (mandible and visor)). Centre of mass and moment of inertia are two factors that affect the stability of a HBS.

There are many things that would need to be standardised in order to define the stability requirement for the HBS. They are as follows:

1. Helmet shell:
    a. Helmet cut/shape
    b. Sizing structure

Since the HBS provides both ballistic and non-ballistic protection, cut/shape standardisation would require a consensus within the community on the area of coverage that the helmet provides. Depending on the helmet cut/shape the centre of gravity may shift. While NATO AEP-2920 was recently revised to cover ballistic testing of helmets, NATO STANAG 2902 would need to be revised in order to capture the additional requirements necessary for a standardised HBS.

In order to standardise helmet shell sizing a consensus would need to be reached based on NATO countries' anthropomorphic head data (which varies based on ethnicity and overall make-up of the users). While this may help standardise the helmet shell size, the use of a suspension system and helmet-to-head standoff could still affect the overall fit and sizing of a helmet.

2. Suspension System:
    a. Blunt impact protection
    b. Helmet-to-head standoff

The level of low-velocity blunt impact protection that a helmet can attenuate and how it is evaluated has not been standardised across NATO, as well as the manner in which it is tested (e.g. modified DOT FMVSS 218). This is dependent on helmet-to-head standoff and the material make-up/design of the suspension system.

Helmet-to-head standoff is a crucial factor that is not standardised. A standoff that goes too far in either direction could affect helmet stability, fit/adjustment, and performance (both ballistically and non-ballistically).

3. Retention System:
   a. Attachment means (hardware or hardware-less)
   b. HBS Movement (medial, lateral, as well as rotational)

How the retention system attaches to the HBS (e.g. 4-point retention system), the means by which it attaches, and how it affixes the helmet to the users head to provide retention and stability are critical to ensuring proper fit of the HBS. Standardisation of the retention systems interface with the helmet shell would be needed in order to define a standard for fit and adjustability (stability). This includes attachment locations, means (hardware or hardware less), and retention system strap sizing and adjustability.

For HBS movement the community would need a standardised test methodology for affixing the HBS onto a headform or other test fixture and having a method and criteria for evaluating movement (front-to-back, side-to-side, and rotational).

Requirement 3.2.1 **(Fit / Adjustment) Mass** – See Section 6.5.2.

Requirement **3.2.2 (Weight) Balance -** Excessive mass carried on the head is detrimental to operational performance, may lead to increased risk of musculoskeletal injury, and is likely to be unacceptable to users. It therefore needs to be minimised, within the constraints imposed by other protection requirements, such as coverage and ballistic performance.

While there are few studies about HBS weight as it relates to subjective comfort, there is no existing medical community validated and injury correlated head borne weight requirement for dismounted Soldiers. Other factors beyond weight/mass that affect balance include centre of mass and moment of inertia of a given HBS and attachments.

Due to the nature of the complex geometry of a helmet, and how they are constructed, ballistic helmets do not maintain uniform areal density. There are numerous helmet cut/shapes and each one can also affect the CM and balance of the helmet.

Requirement **3.6.1 (Situational Awareness) Field of View** – The visual requirements for a dismounted combatant are to maintain a full, unrestricted FoV and ability to scan his/her surroundings to enable perception of visual cues. The ability for a soldier to view their team, their equipment, and their surroundings is paramount.

The HBS design must provide maximum head protection but also allow for situational awareness. Relative to field of view, the design should allow for full peripheral vision when not impeded by an ocular device e.g. NVG, or protection e.g. goggles. Use of any maxillofacial protection must not result in degradation of the inferior field of view when head is forward facing.

Clothing or load carriage must not alter the positioning of the helmet on the head such that field of view is impeded. This is particularly important when in the prone position.

Degradation of the field of view of a HBS can be measured using a perimetry test when assessing a HBS design or adding ocular protection or devices.

Requirement **3.6.2 (Situational Awareness) Hearing (localisation, attenuation)**

Requirement **3.6.3 (Situational Awareness) Speech** – The ability to communicate verbally in an operational scenario is a critical part of operational success. The HBS by nature of its basic design can inhibit hearing capability. The HBS must therefore make consideration for improved hearing capability but also for full speech articulation ability.

The ability to fully enunciate speech at various decibel levels (whisper to shout) is a universal requirement for HBS users. A standard element of a HBS would be to ensure speech capability is not impaired in a basic configuration by elements such as the chin strap, retention system or ocular protection.

Challenges to meet will be in providing voice amplification when the HBS is configured outside of a basic level e.g. with gas mask, full face visor or communications equipment.

In relation to interoperability, speech is an element which provides unique opportunities to utilise technology systems to provide translation applications to the user. These can be as part of the HBS or integrated through a Soldier System technology platform.

9.1.4 Operational Requirements

Requirement **4.2.1 (Compatibility) Clothing –** The wearing of clothing, and more specifically the ballistic protection equipment, must not have any influence on the comfort of the HBS and vice versa.

Especially in the region of the neck, if a ballistic collar is worn, interference is possible. In a kneeling position, lying down or while taking a shooting position, the neck protection must not push the HBS into an uncomfortable position. The construction of the ballistic neck protection must not limit the ability to move the head while wearing the HBS.

The HBS must stay functional at all times, including when worn with full ballistic protection.

Requirement **4.2.2 (Compatibility) Load Carriage** – The load carriage must not limit the ability to move the head while wearing the HBS.

The load carriage must not cause extra pressure on the back of the head in different tactical positions, marching or running.

Requirement **4.2.3 (Compatibility) Weapon** – The helmet needs to accommodate the requirement to gain a weapon sight picture in all firing positions – standing, kneeling and prone. Interference between the helmet brow and sight will cause frustration at best, and possibly inaccurate firing or the need to remove the helmet.

Requirement **4.2.4 (Compatibility) Handset** – The use of a handset with the HBS should not be in conflict with the shape of the helmet. The user must specify make and model to reduce the possibility of interoperability problems with the system. The retention system should not cover the ear on either the left or the right side, so that the user can have the choice to use the handset on both sides.

Requirement **4.2.5 (Compatibility) Gloves** – The HBS should be easy to use with five finger gloves and mittens in all types of climates specified by the user or agency. It must be possible to adjust the retention system with gloves or mittens on, without removing the HBS or any of the attached equipment. This ensures protection is not compromised.

Requirement **4.2.6 (Compatibility) CBRN Personal Protective Equipment (PPE)** – Respirators and hoods are to be worn together with other HBS sub systems (e.g. Helmet, communication equipment) in CBRN scenarios. The CBRN sub systems provide an additional layer between the head and other HBS sub systems and therefore have a large effect on the HBS functionality.

Respiratory protective devices generally comprise a means to seal the eyes, respiratory tract, and gastro-intestinal tracts, and the head (or part of it) from the environment, to prevent ingress through the mouth or nose or contact with the eyes and skin of the head of all chemical and biological agents, or radioactive particles. This requires a leak-tight seal between respirator and facial skin, including the chin and forehead. The dermal protection requirements of AEP-38 should be applied to the areas of skin covered by respirators.

A given respirator and hood is likely to interfere with the helmet suspension system on the forehead and the retention system on the chin, resulting in a sub-optimal fit of the helmet. A given helmet may interfere with the respirator face seal resulting inward leakage and discomfort due to pressure points. By trial and error or co-design of sub systems, a nation will optimise its own HBS in this aspect, but the ability to exchange the CBRN dedicated sub systems remains limited.

Designing HBS and CBRN sub-systems individually and independently, even with strict controls over integration, may only ever lead to a sub-optimal solution given the limitations of trying to integrate existing equipment in an area that is already congested. A fully integrated HBS/CBRN system would offer the biggest benefits in terms of protection, functionality, ergonomics, lightness, stability and comfort. This approach will need close collaboration between HBS and CBRN manufacturers.

From a standardisation point of view various approaches may be possible:

- Define specific areas of the face to be covered. Industry solutions would need to meet these coverage requirements. However, this approach is limited by the variability in facial dimensions;
- Standardise the design of the components most likely to interfere. Again, the variability in head forms and facial dimensions will determine whether these parts will be able to provide a smooth fit;
- Ensure sizing systems for sub systems match (assuming a correlation between skull and facial dimensions may simplify this);
- A set of standard requirements and test procedures may lead to a wider range of compatible products in the long term.

The coverage of the remaining areas of the face and head requires the ability to accommodate a hood beneath the suspension system, and ability to adjust the suspension and retention system of the helmet while wearing CBRN gloves. This requires standards for suspension system adjustment, retention system length and fasteners.

Requirement **4.2.8 (Compatibility) Power** – Selection of an agreed family of batteries that will be compatible with all individual systems would reduce the burden on the Soldier, who would otherwise need to carry multiple batteries. This is important for the development of individual systems capable of operating from a central power source, in addition to their principle power source. Improvements in Soldier Systems will: make use of common components; utilise improved battery chemistry; be more sustainable; and, enable the Soldier to operate independently for extended periods of time due to increased power at reduced weights. Optimising efficiency through physical integration of Soldier System peripherals to a common power source should be considered. Integration of systems operating off a single central power source is extremely complex. Soldier Systems gain efficiency through the integration of low power electronics, power management technologies to minimise energy drain, and the use of improved power and energy dense sources. The integration of energy status displays provides Soldiers and leaders the means to better monitor and manage their system power rate of charge during mission.

– The eventual aims are to provide a common connector, allow wireless power and data transmission to the head system from the body network, and reduce neck torque (through controlled loads and balance, and lower centre of gravity).

Requirement **4.2.9 (Compatibility) Data** – There exist a remarkable number of data transfer protocols and software languages within electronic equipment throughout the world. Standardisation must be achieved in order for equipment of different nations to be used in conjunction with each other.

Electronic equipment, although workable, is sometimes made inefficient (increased power consumption, slow speeds) by the need for its software to interoperate with other software written in a different language. The use of interpreters and data types that would lead to efficiency losses must therefore be minimised, both within the equipment and between that of different nations.

Requirement **4.3.2 (EM Effects) Interference** – EMI (Electromagnetic interference has the potential to significantly disrupt or damage any sensitive electronics on a HBS if not adequately protected/shielded against. A poorly protected component could introduce a vulnerability to the whole system.

The frequencies and field strengths which any HBS mounted equipment will need to be shielded against should be defined; interoperability of equipment would require this.

Outstanding challenges are identifying the expected tolerances and emissions of any planned HBS equipment and then agreeing limits.

The passage of information through any medium is almost universally prone to corruption or loss of clarity due to interference. Any electronic equipment in use on the battle field must therefore be protected from interference by either shielding, use of algorithms, or a novel approach. Though the exact approach chosen by a nation need not be the same throughout all nations, the effect should be. The degree of susceptibility by interference of any nation's HBS or sub-system should be standardised so that likely integrity of information can be understood and planned for by all nations involved in a mission.

Requirement **4.4.5 (Readiness) Storage** – Helmets are typically going to be stored in one of three levels of storage. Using non-country specific terminology these are level 1 – with the Soldier; level 2 – unit level stores; Level 3 – depot holdings. Each level of storage has unique elements required to ensure both the protection of the helmet from damage and the ability to quickly access it for readiness.

Level 1 storage could be defined as the day to day storage of the helmet when not worn. This could be either in barracks/home or in the field (tentage or vehicle). Soldiers are responsible for maintaining the condition of the helmet and ensuring it is stored in a manner that allows easy access in any conditions.

Level 2 storage is for spares or pre-deployment storage for helmets. Helmets stored at unit level need to be protected from damage due to handling and must be able to be easily found in the supply system for rapid issue.

Level 3 storage would involve storage of new, spare helmets for issue to units or individuals. Risks to helmets in this storage level are damage from handling and an inability to locate stock due to poor location marking and complexity/size of storage areas.

HBS components, such as NVG, communications, eye protection, etc. will require similar levels of storage for level 2 and 3. For Level 1, typically items will be stored in pouches located on the Soldiers fighting rig or stored in purpose built cases.

Requirement **4.4.6 (Readiness) End of Life Type** – HBS helmets and components must be considered in terms of whether they are serviceable any time they are pulled for operational use from level 1, 2, or 3 storage. Individual components that can be visually or functionally verified in real time (e.g. inspect helmet cover, power on optic) are a lesser risk to readiness and can be more readily managed. Latent or undiscoverable performance issues (e.g. ballistic performance degradation) are of more concern.

In the absence of real time serviceability verification methods, estimating the service life/end of life is important to plan for and achieve operational readiness. HBS service life data collection and analysis is critical particularly as it pertains to helmet ballistic and impact performance. Even though there is not demand for same ballistic requirements across nations, sharing of service life analyses can help NATO interoperability in achieving high level estimates of service life, possibly by helmet material type, composition, or process. In pursuit of interchangeability in cooperative missions, it would be useful to understand a conservative estimate of service life for any given helmet pulled from storage and placed into service. This estimate in combination with knowing the specification of a given system is key to identifying whether that helmet provides a minimum level of protection.

Requirement **4.6 (Training)** – Training is key to ensuring that Soldiers not only wear HBS mounted equipment correctly to ensure maximum comfort and fit, but also to ensure that maximum efficiency of the equipment is realised.

Training is specific to each nation, usually including specific equipment and techniques and procedures, with the ability to standardise training across NATO limited. However, this opportunity can be realised though NATO exercises specifically interoperating.

The challenge with standardising training is the complexity of differing roles across nations, as well as the varying HBS equipment types, models and capabilities.

Requirement **4.8.1 (Compatibility) Soldier System** – As stated in the definition of a HBS: "A Head Borne System is any incorporated set of equipment worn on the head and meant to work independently or in concert with other components or sub-systems of a DSS." The goal should be to apply a 'system of systems' approach to the Soldier System to ensure that all elements have been designed with optimisation and integration in mind. Internal integration and compatibility internal within individual Soldier Systems and external across multiple national and NATO Soldier

Systems must be considered. Each nation has the mission to apply Systems Engineering best practices in pursuing proper internal Soldier Systems integration and compatibility. Better understanding of NATO functional and mission requirements and allocating those requirements down into physical and functional interface requirements is important if Soldier System compatibility is to be improved.

Requirement **4.8.2 (Compatibility) Vehicle Mounted Systems** – Two types of head borne systems must be taken into consideration: infantry helmets and helmets specifically designed for vehicle crewman.

The ideal situation for infantry is to wear the same helmet, in- and outside the vehicle. Therefore it is important that systems connected from the helmet to vehicles are compatible, e.g. audio-display, visual display, power- and data connections, etc.

It is also important that the dimensions and the shape of infantry helmets are compatible with the sp ace and geometry inside vehicles.

Helmets specifically designed for vehicle crewman:

These types of helmets are often developed in conjunction with the vehicle system. Compati bility issues are therefore taken into account in the development phase of the whole system. Drivers, gunners, vehicle commanders etc. must be able to fulfil their tasks without any inter ference while wearing their helmet.

Requirement **4.8.3 (Compatibility) Seaworthiness** – With respect to ships and landing craft vehicles etc., the same subdivision as with vehicle mounted systems can be made. Compatibility issues as mentioned above are applicable to this section.

Some nations may prescribe additional protective requirements to mitigate the effects of bucketing of the helmet/head from hitting water at high speed.

Requirement **4.8.4 (Compatibility) Airworthiness** – With respect to aircraft and landing craft vehicles etc., the same subdivision as with vehicle mounted systems can be made. Compatibility issues as mentioned above are applicable to this section.

The standardisation required depends upon the requirement for wearers to parachute in the same general service helmet, or connect to the aircraft’s communication system.

9.2 National Specific Requirements/Functionality with No Impact on Co-operative operations

9.2.1 Protection Requirements

There are national sensitivities relating to the threats. Each nation may have requirements either outside the NATO base requirements or driven by different intelligence pictures of the threat, but these are varied, hence it was decided that specific details would not be provided in this document.

This may lead to different test requirements and methods.

9.2.1 Protection Requirements

Requirement **1.2.3 (CBRN) Nuclear Flash**
Requirement **1.4.2 (Light) UV**
Requirement **1.6.1 (Radiation) Thermal**
Requirement **1.6.2 (Radiation) EM**
Requirement **1.7.2 (Flame) Thermal Injury**
Requirement **1.8 (Environment)**
Requirement **1.10 (Insects)**
Requirement **1.11.1 (Edged Weapons) Stab**
Requirement **1.11.2 (Edged Weapons) Slash**
Requirement **1.12.1 (Infection) Mould and Fungus**
Requirement **1.12.2 (Infection) Bacteria**
Requirement **1.12.3 (Infection) Skin Irritation**

9.2.2 Non-Protective Functions

Requirement **2.1.1 Image intensifier (optical sensors)**
Requirement **2.1.2 Thermal imager (optical sensors)**
Requirement **2.2.2 Weapon mounted (visual display)**
Requirement **2.3.1 Microphone (audio display)**
Requirement **2.3.2 Earphone (audio display)**
Requirement **2.4 Haptic display**
Requirement **2.5.1 Radio (antennae)**
Requirement **2.5.2 GPS (antennae)**
Requirement **2.5.3 Mounts and connectivity (antennae)**
Requirement **2.6 Eye correction**
Requirement **2.8 Biosensors**

9.2.3 Ergonomics Requirements

Requirement **3.1.1 (Fit / Adjustability) Comfort**
Requirement **3.1.2 (Fit / Adjustability) Sizing**
Requirement **3.1.3 (Fit / Adjustability) Stability**
Requirement **3.2.1 (Weight) Mass**
Requirement **3.2.2 (Weight) Balance**
Requirement **3.4.1 (Respiration) In / Exhalation Resistance**
Requirement **3.4.2 (Respiration) CO_2**
Requirement **3.5.1 (Heat and Moisture Management) Heat**
Requirement **3.5.2 (Heat and Moisture Management) Moisture**
Requirement **3.5.3 (Heat and Moisture Management) Fogging**
Requirement **3.7 Fogging**
Requirement **3.8.1 (Use) Speed**
Requirement **3.8.2 (Use) Operation**
Requirement **3.8.3 (Use) Usability**
Requirement **3.9.1 (Sustenance) Nutrition**
Requirement **3.9.2 (Sustenance) Hydration**
Requirement **3.10 Vomit and saliva**
Requirement **3.11 Personal identification**
Requirement **3.12.1 (Other) Smoking and related similar activities**

9.2.4 Operational Requirements

Requirement **4.1.1 Tolerance (time on task)**
Requirement **4.1.2 Battery (time on task)**
Requirement **4.2.7 Displays (not worn on the helmet)**

Requirement **4.3.1 Anti-jamming**
Requirement **4.4.1 Battlefield hardening (readiness)**
Requirement **4.4.2 Graceful degradation (readiness)**
Requirement **4.4.3 Maintenance (readiness)**
Requirement **4.4.4 Repair (readiness)**
Requirement **4.4.7 Decontamination (readiness)**
Requirement **4.5.1 Water absorption (environmental resistance)**
Requirement **4.5.2 Weather resistance (environmental resistance)**
Requirement **4.5.3 Oil (environmental resistance)**
Requirement **4.5.4 Solvents (environmental resistance)**
Requirement **4.5.5 Salt water (environmental resistance)**
Requirement **4.5.6 Waste (environmental resistance)**
Requirement **4.7 Cost**

10. POSSIBLE COMPONENTS AND MODULES

10.1 Components

The list provide in Table 7 was produced to specify components belonging to functionalities. They could be combined to modules, to cater for the variance in needs, and to define the interoperability requirements on these modules.

Table 7 - HBS Components and Modules

Functionality	Components
Ballistic protection:	Shells in degrees of head coverage:
	Face and ears free, allowing for use of classical respirator and ear muffs
	Face free, cheeks and ears covered, with integrated audio system, allowing for use of classical respirator and visor
	Full coverage, lower face covered by hard part
	Protective visor, storage under the hard shell or over the hard shell under a cover
	Suspension system, acting as a platform for communication system
CBRN protection:	Masks with various coverage:
	Half mask with hard shell
	Soft half mask, depending on shell
	Full face respirator
	Filter canister(s)
	CBRN hood
	Climate control unit, flushing helmet with clean air
Protection of senses:	Laser eyeglasses
	Ear muffs or ear plugs
Information:	Eye correction
	HMD with optics, for data and images
	II and/or TI with custom optics (alternative: with video interface) audio display (for environmental sound) with noise protection and integrated voice
	Microphone
	CID sensor and response
Connectivity:	Weatherproof, embedded electronics (audio, data, addressing, status sensors, pre-amplifiers)
	Data connector
	Battery and /or (auxiliary) power connector

10.2 Casting modules

Modules are meant to create diversity in HBS configurations. Too many modules are confusing to the user and it will be hard to teach them the right use. Storage and availability may get problems. Use of too few modules will not provide the desired flexibility. This is a balance without a distinct solution. Nations may differ in their operations and sorts of troops. However, the lead idea in casting modules is that:

- The majority of operations can be carried out with the selected configurations;
- Conversion between configurations can be easily made, following change in operation;
- Combinations of few modules create the configurations.

11 CONCLUSIONS

The aims of this study were to identify and describe the interoperability issues of HBS, to define a progressive standardisation priority list and to define the responsibility of NATO and of the DSS-producing nation with respect to interoperability issues.

The study provides a distinct list of issues that need to be addressed to progressively obtain interoperability. The kernel of the study is a proposal to split priorities in levels and assigning responsibilities for their propagation. Roughly summarised, NATO should take the lead for operability issues that could potentially harm the success of a coalition operation or could potentially harm the safety of coalition troops. Nations should take the lead where their own safety or effectiveness is at stake. This is interpreted as a minimal envelop of requirements that should be met to be capable of operating with other nations. The envelope may be widened and detailed to the will of the nation. In particular, criterion values for protection or function, exceeding the minimum, are national responsibilities. It is recognised, however, that common specifications would make the market for HBS and the logistical assistance to other nations transparent.

It is recognised also, that integrated HBS is at its infancy as a product. The first attempts to integrate all the head related functions in a single product, to the benefit of the Soldier, are currently made. NATO is facing the dilemma that standardisation in an early phase has the risk of making the wrong choices, whereas standardisation in a late phase has to fight choices already made. Therefore this document is recommended as a guideline for the HBS developments in the near future, trusting that this may help to focus and ease later standardisation.

Table 8 recommends the areas for commonality in HBS standards, and proposed areas for standardisation, identifying, where apocopate, STANAGs already exist:

Table 8 - Prioritised identification of HBS related NATO agreements

Priority	**Requirement**	**Existing STANAG**
Priority 1: Mission ineffective or loss of life because of incompatibility of HBS	1.1.1 Penetration resistance (ballistic / fragment impact)	STANAG 2920 / STANAG 4296
	1.1.2 BABT mitigation (ballistic / fragment impact)	STANAG 2920
	1.4.1 Directed energy (laser)	STANAG 4495 /
	1.5.1 Impulsive (noise)	
	1.7.1 Flame resistant (flame)	AEP 2902
	1.9 Low energy impact	-
	2.1.1 Image intensifier (optical sensors)	-
	2.1.3 Mounts and connectivity (optical sensors)	AEP 2902
	2.2.4 Mounts and connectivity (visual display)	-
	2.2.5 Level of detail (visual display)	AEP-2013 STANAG 7041
	2.2.6 Display symbology (visual display)	AEP-2013
	2.3.1 Microphone (audio)	-
	2.3.2 Earphone (audio)	-

	2.3.3 Enhanced hearing (audio)	STANAG 4677
	2.3.4 Mounts and connectivity (audio)	-
	2.7.1 Noise (signature management)	-
	2.7.2 Reflectivity (signature management)	STANAG 2835
	2.7.3 Near IR (signature management)	-
	2.7.4 Thermal (signature management)	-
	2.7.5 EM (signature management)	-
	2.9 Combat ID	STANAG 4579
	2.11.1 Network (power / data transmission)	
	2.11.2 Power (power / data transmission)	/ STANAG 4695
	2.11.3 Connectors (power / data transmission)	
Priority 2: Mission ineffective or loss of life because inability to exchange a HBS or components	1.2.1 Respiratory protection (CBRN)	STANAG 4155, AEP-73 Ed B V1
	1.2.2 Dermal protection (CBRN)	AEP-38 Ed B Vol 1 V2 AEP-38 Ed B Vol 2 V1
	1.3.1 Primary (overpressure)	-
	1.5.2 Other excessive noise (noise)	-
	2.1.2 Thermal imager (optical sensors)	-
	2.2.1 Helmet mounted (visual display)	STANAG 7041
	2.5.2 GPS (antennae)	-
	2.10.1 Chem / bio threat sensors (environmental sensors)	-
	2.12.1 Buttons (interfaces)	-
	2.12.2 Voice activated (interfaces)	-
	2.12.3 Mounts and connectivity (interfaces)	STANAG 4694 . AEP 2902
	3.1.1 Comfort (fit / adjustability)	AEP 2902
	3.1.2 Sizing (fit / adjustability)	AEP 2902
	3.1.3 Stability (fit / adjustability)	AEP 2902
	3.2.2 Balance (weight)	-
	3.6.1 Field of view (situational awareness)	-
	3.6.2 Hearing (situational awareness)	-
	3.6.3 Speech (situational awareness)	-
	4.2.1 Clothing (compatibility)	
	4.2.2 Load carriage (compatibility)	-
	4.2.3 Weapon (compatibility)	-
	4.2.4 Handset (compatibility)	-
	4.2.5 Gloves (compatibility)	-
	4.2.6 CBRN Personal Protective Equipment (PPE) (compatibility)	-
	4.2.8 Power (compatibility)	
	4.2.9 Data (compatibility)	STANAG 4677
	4.3.2 Interference (compatibility)	-
	4.4.5 Storage (readiness)	-
	4.4.6 End of life type (readiness)	-

	4.6 Training	-
	4.8.1 Soldier System (compatibility)	
	4.8.2 vehicle mounted systems (compatibility)	-
	4.8.3 Seaworthiness (compatibility)	-
	4.8.4 Airworthiness (compatibility)	-

12 RECOMMENDATIONS

1. Participating nations are recommended to apply the methods and approaches as described in this document;

2. Nations are invited to propose alterations to the methods presented in the event that the development of future systems or technological change(s) dictates further refinement. Such proposals should be submitted, at the earliest possible opportunity, to the Defence Support Division where they will be processed in the same manner as the original agreement;

3. LCGDSS should use this document, specifically Table 8, to identify dormant STANAGs, and possibilities for reviewing or developing standardisation between HBS equipment in order to enhance interoperability.

Annex A - REFERENCES

Other NATO documents:

HFM-RTG-266 (3D Scanning for Clothing and Logistics Soldier System
NATO SET-249 Laser Eye Dazzle Threat Evaluation and Impact on Human Performance Activity
Interoperability - Main principles
Battlefield Threats and Hazards to the NATO Dismounted Soldier System
AEP-2013 Soldier Symbology Edition 1 DRAFT Version 1 October 2013
AEP-38 – Operational Requirements, Technical Specifications and Evaluation Criteria for CBRN Protective Clothing
DefStan 23-12 UK Generic Soldier Architecture
2047 EMERGENCY ALARMS OF HAZARD OR ATTACK (NBC AND AIR ATTACK ONLY)
2835 NATO ULTRAVIOLET REFLECTIVE (UVR) WHITE COLOUR FOR THE CAMOUFLAGE OF MILITARY EQUIPMENT IN SNOW ENVIRONMENTS (Confidential)
2836 REMOVABLE PAINTS FOR CAMOUFLAGE
2902 NON-BALLISTIC TEST METHODS AND EVALUATION CRITERIA FOR COMBAT HELMETS
2920 BALLISTIC TEST METHOD FOR PERSONAL ARMOUR MATERIALS AND COMBAT CLOTHING
3151 CODIFICATION - UNIFORM SYSTEM OF ITEM IDENTIFICATION
4155 NBC PROTECTIVE MASK AND FILTER CANISTER SCREW THREADS
4201 MARKING OF RIOT CONTROL AND TRAINING CANISTERS
4296 EYE PROTECTION FOR THE INDIVIDUAL SOLDIER - BALLISTIC PROTECTION
4370 ENVIRONMENTAL TESTING
4475 DESIGN CRITERIA FOR AN NBC MASK DRINKING SYSTEM (MDS)
4495 EYE PROTECTION FOR THE INDIVIDUAL SOLDIER - LASER PROTECTION
4512 DISMOUNTED PERSONNEL TARGET
4579 BATTLEFIELD TARGET IDENTIFICATION DEVICE (BTID) WAVEFORM TECHNICAL CHARACTERISTICS
4677 DISMOUNTED SOLDIER SYSTEMS STANDARDS AND PROTOCOLS FOR COMMANDER, CONTROL, COMMUNICATIONS AND COMPUTER (C4) INTEROPERABILITY
4695 POWER SOURCE INTEROPERABILITY
4845 NATO GENERIC SOLDIER SYSTEM REFERENCE ARCHITECTURE
4851 COMBINED POWER AND DATA ACCESSORY CONNECTOR FOR DISMOUNTED SOLDIER SYSTEMS (DSS)
AAP-6 NATO GLOSSARY OF TERMS AND DEFINITIONS (ENGLISH AND FRENCH)
AAP-15 NATO GLOSSARY OF ABBREVIATIONS USED IN NATO DOCUMENTS AND PUBLICATIONS
AdatP-34 THE NATO C3 TECHNICAL ARCHITECTURE (NC3TA)
AEP-7 NUCLEAR BIOLOGICAL, CHEMICAL (NBC) DEFENCE FACTORS IN THE DESIGN, TESTING AND ACCEPTANCE OF MILITARY EQUIPMENT
AEP-25 NUCLEAR BLAST AND THERMAL TEST METHODS AND PROCEDURES
AEP-38 OPERATIONAL REQUIREMENTS, TECHNICAL SPECIFICATION AND EVALUATION CRITERIA FOR NBC PROTECTIVE CLOTHING
AEP-73 COMBINED OPERATIONAL CHARACTERISTICS, TECHNICAL SPECIFICATIONS, AND EVALUATION, TESTS AND CRITERIA FOR PROTECTIVE MASKS
AJP-4 ALLIED JOINT LOGISTICS DOCTRINE
AJP-4.5 ALLIED JOINT HOST NATION SUPPORT DOCTRINE & PROCEDURES
ANP-2 INTRODUCTION TO NAVSTAR GPS USER EQUIPMENT
ATP-65 THE EFFECT OF WEARING NBC INDIVIDUAL PROTECTION EQUIPMENT ON INDIVIDUAL AND UNIT PERFORMANCE DURING MILITARY OPERATIONS
HEALTH AND SAFETY EXECUTIVE (UK) CONTROL OF NOISE AT WORK REGULATIONS 2005

US military helmet standards

MIL-H-44099A	PASGT Helmet
MIL-STD-662E	Aramid Ballistic Cloth
MIL-C-44050OA	Ballistic Acceptance Test
MIL-STD-105D	Sampling Procedures
MIL-I-4S208A	Quality System

UK military helmet standards

VIRTUS ITEAP 3.2	VIRTUS Head Sub-System
DefStan 00-35	Generic Soldier Architecture (GSA)

DEU helmet standards

HVN 2009	Prüfrichtlinie „Durchschusshemmender Helm mit Visier und Nackenschutz“ VPAM 2010

Technische Richtlinie TR Ballistischer Helm, Polizei des Bundes 2010

List of abbreviations

BHBT	Behind Helmet Blunt Trauma
BMS	Battlefield Management System
BS	British Standard
C4I	Command, Control, Communication, Computing, Information
CID	Combat Identification
CO_2	Carbon Dioxide
CVC	Combat Vehicle Crew
DSS	Dismounted Soldier System
EM	Electro Magnetic
EN	European Norm
GPS	Geographical Positioning System
HBS	Head Borne System
HAAP	Helmet As A Platform
HMD	Head Mounted Display
HUD	Heads Up Display
ID	Identity
II	Image Intensification
IR	Infrared
LG	Land Group
N	Nuclear
NBC	Nuclear, Biological, Chemical
STANAG	Standardisation Agreement
TI	Thermal Imager
W	Watt