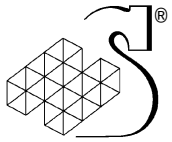

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DEVELOPMENT AND EVALUATION OF SOLDIER SYMBOLOGY

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ABSTRACT

Future soldier systems are being developed that can display a soldier's geo-location on a portable, wearable digital display but common NATO symbology does not exist for displaying these soldiers on a map. NATO Land Capability Group 1 (LCG 1) has identified a need to develop and validate common symbology for the individual soldier that can be displayed on a wide range of digital display types, to improve the joint interoperability of NATO C4I information systems at the dismounted soldier level.

National symbology sets were provided by LCG1 for a heuristic analysis based on symbology standards and guidelines in the military domain, and in the areas of human factors and symbol adaptability to digital displays. The review of existing symbol sets, provided by LCG1 indicated that they generally fell short of the ideal. A new symbol concept was developed to better conform to the heuristic framework and a future plan of laboratory and field testing was proposed.

Suggestions for improving the design and development of soldier system symbology are provided and opportunities afforded by hardware and software capabilities are discussed.

RÉSUMÉ

On met au point des systèmes de combattant du futur qui peuvent indiquer la position géographique d'un soldat sur un écran numérique portable, sauf qu'une symbologie commune de l'OTAN n'existe pas pour l'affichage de ces soldats sur une carte. Le 1er Groupe de l'OTAN sur les capacités terrestres (LCG 1) a cerné la nécessité de mettre au point et de valider une symbologie commune pour chaque soldat qui peut être affichée sur une grande gamme d'écrans numériques, afin d'améliorer l'interopérabilité interarmées des systèmes d'information C3IR de l'OTAN au niveau du soldat débarqué.

Des ensembles de symbologie nationale ont été fournis par le LCG 1 pour une analyse heuristique fondée sur des normes et des directives de symbologie dans le domaine militaire, ainsi que de l'ergonomie et de l'adaptabilité des symboles aux écrans numériques. L'examen des ensembles de symboles existants, fournis par le LCG 1, indique qu'ils ne sont pas à la hauteur des attentes. Un nouveau concept de symboles a été élaboré afin de mieux respecter le cadre heuristique, et on a proposé un plan futur d'essai en laboratoire et sur le terrain.

Des propositions pour améliorer la conception et le développement de la symbologie du système de soldat sont fournis, et on discute des possibilités offertes par les capacités matériel et logiciel.

EXECUTIVE SUMMARY

Introduction: Future soldier systems are being developed that can display a soldier's geo-location on a portable, wearable digital map. Many nations intend to provide blue-force tracking on their soldier computers so that the positions of all, or select members of a unit, can be observed in real time on the same digital map display. While a NATO standard (APP-6A) exists for military symbols for Land systems, it does not include symbology to identify individual soldiers. APP-6A uses a Symbol Ideinfification Coding (SIDC) to cateogrize five groups of symbol sets for a) units and equipment, b) military operations, c) meteoroogical and oceanographic, d) signals intelleigence and e) military operations other than war. The NATO Land Capability Group 1 (LCG 1) identified a need to develop and validate common symbology for the individual soldier that can be displayed on a wide range of digital display types, to improve the joint interoperability of NATO C4I information systems at the dismounted soldier level.

Aims: The aims of this project were to: review existing dismounted soldier symbol sets from members of LCG1, representing individual soldiers up to Company level, for consistency with land operations and human factors guidelines; develop or recommend a set of symbols that satisfy these requirements; and propose a programme of test and evaluation to validate the suitability of these and related symbol sets across a range of different soldier system display technologies.

Method: LCG1 provided several national symbol sets for evaluation. A heuristic analysis of these sets was developed by consulting symbology standards and guidelines in the military domain, and in the areas of human factors and symbol adaptability to digital displays. Based on criteria extracted from these standards and guidelines, an analytical framework was developed to provide both a standardized method of evaluating the candidate symbol sets, and a basis for designing a new symbol set, if required. This framework was applied to all candidate and new symbol sets.

Results: The review of existing symbol sets, provided by LCG1, against the heuristic framework indicated that they generally fell short of the ideal. Most symbol sets failed to conform to fundamental APP-6A design requirements and design features were often subject to problems of discrimination in highly textured map and satellite imagery backgrounds and with symbol overlap. Many candidate symbols were difficult to discriminate when reduced in size or display resolution. A new symbol concept was developed to conform better to the heuristic framework and a plan of laboratory and field testing was developed.

Discussion: Issues associated with design and development of soldier system symbology are discussed that better optimize design attributes to display characteristics and expand the symbol sets to include operational icons and functions. The implications and opportunities afforded by future soldier system hardware and software capabilities on soldier symbology design are discussed, with a view to improving symbology set usability, functionality, and customizability.

Future Plans: We recommend that any candidate symbol set be taken through a rigorous series of laboratory and field testing with representative users, using representative tasks in representative conditions to validate and refine the design.

SOMMAIRE

Introduction : On élabore actuellement des systèmes de combattant du futur qui peuvent afficher la position géographique d'un soldat sur un écran numérique portable. Beaucoup de pays veulent offrir le suivi de la force bleue sur leurs ordinateurs du soldat afin que les positions de tous les militaires, ou de militaires particuliers d'une unité soient observées en temps réel sur la même carte numérique. Même si une norme de l'OTAN existe (APP-6A) pour les symboles militaires des systèmes terrestres, elle ne comprend pas la symbologie pour identifier chaque soldat. La norme APP-6A utilise un code d'identification du symbole pour classer les ensembles de symboles selon cinq catégories : a) unités et équipement, b) opérations militaires, c) météorologie et océanographie, d) renseignement d'origine électromagnétique et e) opérations militaires autres que la guerre. Le 1er Groupe de l'OTAN sur les capacités terrestres (LCG 1) a cerné la nécessité de mettre au point et de valider une symbologie commune pour chaque soldat qui peut être affichée sur une grande gamme d'écrans numériques, afin d'améliorer l'interopérabilité interarmées des systèmes d'information C3IR de l'OTAN au niveau du soldat débarqué.

But : Les objectifs de ce projet sont les suivants : examiner la cohérence avec les opérations terrestres et les lignes directrices de l'ergonomie des ensembles existants de symboles du soldat débarqué pour les membres du LCG1, qui représentent les soldats individuels jusqu'au niveau de la Compagnie; élaborer ou recommander un ensemble de symboles qui satisfait à ces exigences et proposer un programme d'essai et d'évaluation pour valider la pertinence de ces symboles et des ensembles de symboles connexes par rapport à une gamme de technologies d'affichage différentes du système du soldat.

Méthode : Le LCG 1 a fourni plusieurs ensembles de symboles nationaux aux fins d'évaluation. Une analyse heuristique de ces ensembles a été effectuée en consultant les normes et les directives de la symbologie dans le domaine militaire, ainsi que dans les domaines de l'ergonomie et de l'adaptabilité des symboles aux écrans numériques. Selon les critères tirés de ces normes et de ces directives, on a établi un cadre d'analyse pour fournir à la fois une méthode normalisée d'évaluation des ensembles de symboles candidats et les éléments essentiels pour mettre au point un nouvel ensemble de symboles, au besoin. Ce cadre a été appliqué à tous les symboles candidats et aux nouveaux ensembles de symboles.

Résultats : L'examen des ensembles de symboles existants, fournis par le LCG 1, en fonction du cadre heuristique a indiqué que les résultats ne sont pas à la hauteur des attentes. La plupart des ensembles de symboles n'ont pas respecté les exigences fondamentales de la norme APP-6A; et les caractéristiques nominales ont souvent fait l'objet de problèmes de discrimination dans des cartes et des fonds d'images satellites hautement texturées et ont connu des problèmes de chevauchement de symboles. La discrimination de beaucoup de symboles candidats a été difficile lorsque la taille de ces derniers a été réduite ou en raison de la résolution d'affichage. Un nouveau concept de symbole a été développé afin de mieux respecter le cadre heuristique, et un plan d'essai en laboratoire et sur le terrain a été élaboré.

Discussion : Les questions liées à la conception et à la mise au point de la symbologie du système de soldat qui optimisent davantage les caractéristiques de conception font l'objet de discussion afin de mettre en évidence les caractéristiques et d'élargir les ensembles de symboles pour inclure les icônes opérationnels et les fonctions. Les répercussions et les perspectives offertes par les capacités matériel et logiciel du système de combattant du futur relativement à la conception de la symbologie du soldat font l'objet de discussions, dans le but d'améliorer l'utilité, la fonctionnalité et la personnalisation de l'ensemble de symbologie.

Recherches futures : Nous recommandons que tout ensemble de symboles candidats passe par une série rigoureuse d'essais en laboratoire et sur le terrain avec des utilisateurs représentatifs, au moyen de tâches représentatives dans des conditions représentatives afin de valider et d'améliorer la conception.

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Acknowledgement

We would like to acknowledge the contributions of Catherine Arruda in supporting our efforts in analysis and report preparation.

1 Background

1.1 Abbreviations and Definitions

Affiliation	The particular unit and sub-unit nomenclature for designating the membership of a soldier entity.
APP-6A	NATO Standard for Military Symbols for Land Systems
C4I	Command, Control, Communications, Computer and Intelligence
Comd	Commander
Coy	Company
Echelon	Echelon denotes the size and command level of a unit.
HSI®	Humansystems Incorporated
LCG1	Land Capability Group 1
NATO	North Atlantic Treaty Organization
NVG	Night Vision Goggle
Pl	Platoon
Rank	Rank denotes a soldier's status or class within a military hierarchy (e.g. private, corporal, captain, major)
Role	The function fulfilled by a particular soldier. Note: role may not necessarily indicate rank.
Sgt	Sergeant
SM	Sergeant Major
SME	Subject Matter Expert
2 i/c	Second in command
USMC	United States Marine Corps

1.2 Future Soldier Systems

Future soldier systems are being developed that can display a soldier's geo-location on a portable digital map, which could be displayed through a helmet-mounted display, weapon sight display, portable digital assistant, mini-tablet, or laptop. Many nations intend to provide blue-force tracking on their soldier system computers so that the positions of all, or select members of a unit, can be observed in real time on the same digital map display (Figure 1). Given this capability, many questions arise as to the ways and means of representing a soldier symbol on a digital map, what information should be displayed, and how will closely clustered soldier symbols be discriminated from each other and the map background.

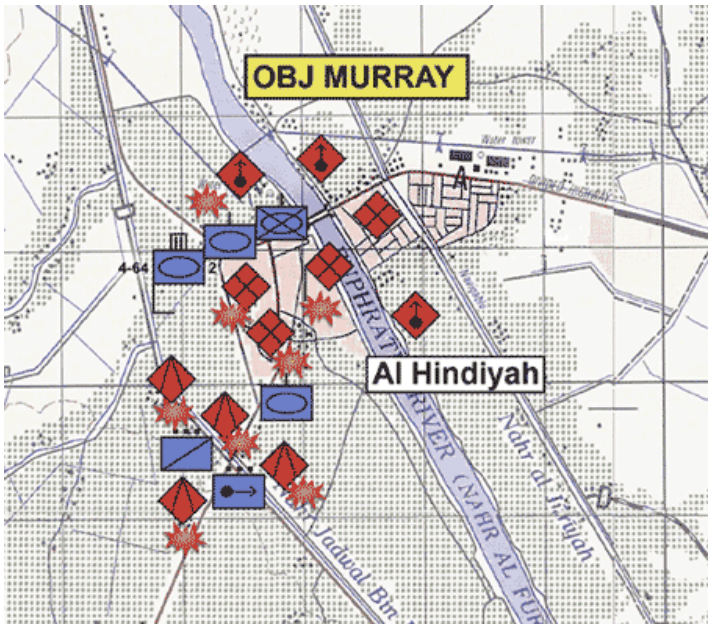


Figure 1: Soldier System Digital Map Symbology

1.3 APP-6A Military Symbols for Land Based Systems

A NATO standard for military symbols for Land systems (APP-6A) exists to provide common NATO operational symbology for interoperability of Land Command, Control, Communications, Computer, and Intelligence (C4I) systems. This standard provides a common symbol hierarchy, information taxonomy, and symbol identifiers, including a standard symbol set for all future NATO C4I operations in the force and engagement domains. Unfortunately APP-6A does not include symbology to identify individual soldiers.

1.4 NATO LCG1 Effort

NATO Land Capability Group 1 (LCG1) has identified a need to develop and validate common symbology for the individual soldier that can be displayed on a wide range of digital display types, to improve the joint interoperability and exchange of data and information between NATO C4I information systems at the dismounted soldier level. Several NATO nations have developed soldier-level symbology for their own purposes but these have not been evaluated as candidates for a standard NATO symbol set. LCG1 requires a systematic assessment of these national symbol sets to validate the selection of either an existing set, a modified version of an existing set, or a new proposed symbol set that better complies with human factors guidelines. This project serves this requirement.

2 Aims

The following aims were identified in the Statement Of Work (SOW) for this project.

1. Review existing symbol sets, representing individual soldiers up to Company level, for consistency with land operations and human factors guidelines.
2. Recommend and/or develop a set of symbols, up to Company level, that satisfy the requirements in #1 above.
3. Propose a programme of test and evaluation to validate the suitability of these and related symbol sets for use on complex backgrounds across a range of different soldier system display technologies.

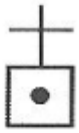
3 Method

LCG1 provided several national land symbol sets for evaluation. To undertake a desktop analysis of these sets, a heuristic framework was developed by consulting symbology standards and guidelines in the military domain, and in the areas of human factors and adaptability to digital displays. Based on criteria extracted from these standards and guidelines, an analytical framework was developed to provide a standardized method of evaluating the candidate symbol sets, and a basis for designing a new symbol set, if required. These steps are described in more detail below.

3.1 Symbol Sets

LCG1 collected symbol sets from the following nations. Examples of national land symbols are shown below. Selected symbol sets are provided in Annex A.

Belgium 

Canada 

Netherlands 

Switzerland 

U.S. Army 

U.S. Marine Corps 

As well, LCG1 has suggested a set of soldier level symbols (LCG1 Proposed) for consideration in this analysis.

3.2 Heuristic Framework

To provide a more objective and standardized approach to the symbol set evaluation, and the development of any new symbol design, a framework of 'heuristics' or rules of thumb were required. Given the NATO focus of this project, we directed our review at identifying the most appropriate international standards to eliminate any national bias in the evaluation or development of a NATO symbol set. Based on this review of standards we determined that there was no single human factors guideline or standard that provided the necessary heuristic framework for the scope of this soldier symbol set evaluation. As a result, we developed our own heuristic framework for this study comprised of the following three criterion areas:

- Military Domain - the framework needed to ensure that any candidate symbol set upholds the design conventions (particularly Land force) that have long been in practice in NATO nations.
- Human Factors Domain – human factors criteria were essential for assessing the usability of any candidate symbol set design.
- Adaptability to Digital Displays – the use of soldier symbology on mobile soldier system computer displays requires that this heuristic consider the range of possible display device capabilities, from low resolution, monochrome equipment displays to high resolution, colour digital maps.

Combined, these three domain areas were judged to adequately encompass the broad range of symbol set usability and employment issues for small unit army applications on mobile computing devices. These domains, and the associated standards and guidelines used in this framework, are described in more detail below.

Military Domain:

Common Land symbology has been in use in NATO nations for many years (i.e. NATO Standard APP-6A "Military Symbols for Land Based Systems"). The conventions in NATO APP-6A are derived from DoD Interface Standard for Common Warfighting Symbology (MIL-STD-2525C). However, the NATO standard APP-6A does not provide sufficient detail to represent the dismounted soldier level.

This standard sets out a number of symbol design conventions that need to be maintained in any future soldier symbology. Tactical conventions include the frame shape, affiliation, status, fill, interior icons, and modifiers for movement, echelon, equipment, text, and so on. Specific guidance is provided for symbol framing, placement of icons and modifiers and design specifications are provided for size, shape, orientation, colour, line width, and so on.

In considering the design of any new symbol set concept for individual soldiers, we used the following criteria for symbol identity and the military display environment, in addition to the requirements already identified for the military domain heuristic from MIL-STD-2525C.

Symbol Identity:

To be comprehensive for soldier identification at Company level and below, we believe that a symbol set must also incorporate the following dimensions.

a) Role: Does the soldier occupy an officer or enlisted role?

b) Echelon: At what echelon is the soldier employed (Company, Platoon, or Section/Squad)?

c) Affiliation: What is the affiliation of the unit that employs the soldier? For example, a Section with the affiliation of 1-3 indicates One Section of Three Platoon.

Using all three dimensions enables a symbol to specifically identify almost any soldier on the battlefield, assuming an intra-section naming convention for soldiers within each sub-unit. Therefore, any future soldier symbol should include identifiers for role, echelon, and affiliation.

Symbol Environment:

Map displays in future soldier systems will likely be characterized by the following conditions.

a) Scale: The scale of soldier system digital maps will be small, mostly focused on immediate areas of influence.

b) Background Clutter: Background clutter will likely be high. Operations are increasingly occurring in built up areas with complex terrain. This introduces more complexity into digital maps and satellite photographs, where external symbol details can be lost in the lines, buildings, and high contrast shadows.

c) Overlapping: Fire teams and Sections/Squads will often work in close proximity to each other and the dynamic flow of battle will result in different sub-units occupying the same battlespace at times. Therefore, it is likely that symbols will overlap each other.

d) Multiple Symbols: In the complex battlespace of the future, the digital map display could be cluttered with many different symbols for friendly and enemy forces, equipment, and structures.

Given this future symbol environment we believe that identifying symbol information needs to reside within the symbol frame and not externally. External modifiers will become obscured and possibly confused by the close proximity of soldier symbols and the background clutter on the small-unit digital map.

Human Factors Criteria:

There are a number of human factors standards from different, related industries that are currently in use to support and govern the design of symbols and icons. By definition, the specific nature of the soldier environment and host technology (i.e. soldier-borne computers) means that care must be taken in extracting only those criteria that are applicable to this particular application. Based on a review of the human factors standards and guidelines (listed below) the following human factors criteria were considered for the heuristic.

- Comprehensibility – the ease with which the meaning of the symbol is understood.
- Discriminability –the ease with which a given symbol can be distinguished from other symbols that might occur in close spatial, temporal or contextual proximity.
- Learnability – the ease with which the meaning of a symbol can be recalled after it has been understood.
- Legibility – the ease with which the graphic detail of a symbol can be discerned.
- Recognizability – the ease with which it is possible to identify a symbol based on previous experiences with the same or similar types of symbols.

The following standards and guidelines were reviewed to derive human factors evaluation criteria.

1. EG 201 379 V1.1.1 - Human Factors framework for development, evaluation, and selection of graphical symbols. Produced by the European Telecommunications Standards Institute, E.G. 201 379 provided human factors guidance for the appropriate use of graphical symbols, development of new symbols, and the evaluation of graphical symbols using the Multiple Index Approach (MIA).

2. ISO/IEC 11581-1 - Information Technology - User system interfaces and symbols - Icon symbols and functions - Part 1: Icons - General. This international standard was intended for the design, implementation, and evaluation of icons for graphical user interfaces to computer-based applications.

3. ISO/IEC 11581-2 - Information Technology - User system interfaces and symbols - Icon symbols and functions - Part 2: Object icons. This extension to Part 1 above applied to icons that are shown on screen that users can manipulate and interact with, and that represent data, or computer system functions.

4. ISO 9186-1 - Graphical symbols - Test methods - Part 1: Method for testing comprehensibility. This standard specified a method for testing the comprehensibility of graphical symbols to test the extent to which a graphical symbol communicates its intended message.

5. ISO 9186-2 - Graphical symbols - Test methods - Part 2: Method for testing perceptual quality. This standard specified a method for testing the perceptual quality of graphical symbols to verify that graphical elements are readily identifiable by the eventual user population.

6. ITU-T F.910 - Human Factors procedures for designing, evaluating, and selecting symbols, pictograms, and icons. This International Telecommunications Union recommends an industry-specific methodology for design, evaluation, and standardization of symbols.

Adaptability to Digital Displays:

We anticipate that future soldier symbology could be displayed on a wide range of screen types with different display characteristics (e.g. monochrome or colour, backlit or reflective, with a broad range of screen resolutions). The standard ISO 80416-4 Basic principles for graphical symbols for use on equipment - Part 4: Guidelines for the adaptation of graphical symbols for use on screens and displays was used to derive digital display evaluation criteria and provided guidelines for the adaptation of symbols to screens and displays for a wide range of equipment and devices. Specifically, issues associated with symbol size, pixel grids, degradation of resolution, and use of colour were considered.

3.3 Analytical Framework

Criteria were extracted from the standards and guidelines in the heuristic framework to develop an analytical framework that would provide a standardized method of evaluating the candidate symbol sets. A five-point scoring scale was applied to each criterion. Each symbol set was then scored by the three authors of this report in a group discussion to arrive at a consensus rating. The analytical framework criteria and associated scoring scales are detailed below.

Military Land Domain:

1. All symbols within the set conform to a rectangular "ground" shape as per the aspect ratios of MIL-STD-2525C (i.e. ratios of 1:1, 1:1.5).

1- does not conform, 3 – conforms to shape but not aspect ratio, 5 – conforms for shape and aspect ratio.

2. Symbols have an appropriate frame border width.

1 – no frame, 3 – frame does not clearly indicate the symbol, 5 – clearly indicates the symbol

3. Symbols use both shape and fill colour to indicate battle dimension.

1 – no, 3 – one option only, 5 - both.

4. Symbol friendly interior elements can be recognizable at the smallest expected symbol size.

1 – not recognizable, 3 – partially recognizable, 5 – fully recognizable

5. Symbol interior elements can be recognizable at the smallest expected symbol size for the following affliliations: Red (Hostile and suspect), yellow (unknown), cyan (friendly) and green (neutral).

1 – not recognizable, 3 – partially recognizable, 5 – fully recognizable.

6. The frame indicates the location status (actual vs planned) of the soldier at the smallest expected symbol size.

1 – no status, 3 – frame does not clearly indicate status, 5 – clearly indicates status

7. Symbols are universally consistent with NATO echelon[1] conventions.

1- not consistent, 3 – partially consistent, 5 – fully consistent.

Human Factors:

1. Role[2] symbols are discriminable from each other.

1- not discriminable, 3 – somewhat discriminable, 5 – fully discriminable.

2. Symbols maintain their integrity when clustered together (not overlapped).

1- no integrity, 3 – medium integrity, 5 – high integrity

3. Symbols convey required information with fewest elements.

1- many elements, 3 – several elements, 5 – few elements

4. Symbols can be replicated easily?(ie drawn by hand on paper)

1- very difficult, 3 – somewhat difficult, 5 – not difficult

5. Symbols can be readily discernible from a temperate map background.

1- not discriminable, 3 – somewhat discernible, 5 – fully discernible.

6. Symbols can be readily discernible from an arid map background.

1- not discriminable, 3 – somewhat discernible, 5 – fully discernible.

7. Symbols can be readily discernible from highly textured map background (lines, buildings, etc).

1- not discriminable, 3 – somewhat discernible, 5 – fully discernible.

8. For discrete icons there is a clear gap between the icon and the surrounding border at the smallest usable size.

1- not discriminable, 3 – somewhat discernible, 5 – fully discernible.

[1] By echelon we mean the military operational unit, which in this case are: company, platoon, section, squad
[2] By role, we mean the military function of the individual, e.g. commander, 2IC.

9. Symbol can accommodate worst-case overlapping direction without loss of discernability.

1 - no overlapping, 3 – some overlapping, 5 – considerable overlapping

Display Issues:

To investigate the effects of symbol size and display resolution on symbol discriminability, symbols were modified to fit a size/resolution matrix according to the following size and resolution configurations:

Size: Symbols were adjusted in size to fit into squares of the following four sizes, while retaining their original height/width proportions. The sizes were selected to represent a wide range of possible symbology sizes for a digital display.

- 20mm x 20mm
- 15mm x 15mm
- 10mm x 10mm
- 5mm x 5mm

Resolution: Symbols were graphically re-sampled into the following four pixel grids, as suggested by ISO 80416-4. A top-down re-sampling, nearest-neighbour image interpolation technique was chosen to represent a typical computer accommodation that might be made by a soldier system.[3] The nearest-neighbour technique was chosen as the most basic and least processor intensive of the interpolation algorithms, to better represent the likely lowest-order soldier system computing device.

- 64 x 64 pixels
- 32 x 32 pixels
- 16 x 16 pixels
- 12 x 12 pixels

These symbol size/resolution matrices are shown in Annex C. A complex example symbol from each set was prepared in each of the size/resolution combinations and then scored for the following criteria.

Note: image printouts should be viewed for pixel matrices since computer displays will employ anti-aliasing techniques to smooth the pixilation.

[3] However, it is recognized that this approach may overestimate the degradation of detail at low resolutions, compared with an approach that optimizes the design for a specific matrix size, as would likely be the case for future low resolution systems that are specifically designed to represent military symbols to the soldier level.

1. The symbols can be discriminated from each other for role at smaller sizes and at lower resolutions?

Scoring indicates the proportion of 16 size/resolution matrix combinations that can be discriminated. Symbol sizes ranges from 20mm, 15mm, 10mm, and 5mm. Symbol resolution ranges from 64x64, 32x32, 16x16, and 12x12 pixels.

1- no combinations, 3 – 50% of combinations, 5 – 100% of combinations

2. The Unit affiliation of symbols can be discriminated from each other at smaller sizes and at lower resolutions?

Scoring indicates the proportion of 16 size/resolution matrix combinations that can be discriminated. Symbol sizes ranges from 20mm, 15mm, 10mm, and 5mm. Symbol resolution ranges from 64x64, 32x32, 16x16, and 12x12 pixels.

1- no combinations, 3 – 50% of combinations, 5 – 100% of combinations

3. The echelon of symbols can be discriminated from each other at smaller sizes and at lower resolutions?

Scoring indicates the proportion of 16 size/resolution matrix combinations that can be discriminated. Symbol sizes ranges from 20mm, 15mm, 10mm, and 5mm. Symbol resolution ranges from 64x64, 32x32, 16x16, and 12x12 pixels.

1- no combinations, 3 – 50% of combinations, 5 – 100% of combinations

4 Results

The results of the analytical framework are described below for each contributing nation's symbol set. As well, a new symbol concept is proposed.

4.1 Symbol Set Scoring

The results of the symbol set scoring is provided in Annex D and described in more detail below.

4.1.1 Symbol Set Results

Results are summarized for each symbol set below.

Belgium: Only two symbols were included in this set: Section Commander and soldier.

- The use of circles with no in-fill and t-crossed lines do not conform to APP-6A conventions of rectangles with light blue in-fill and interior icons.
- Since only one echelon is represented we do not know how this concept could be extended to represent other echelons and roles.
- The lack of in-fill colour may make the symbols less discriminable against map backgrounds. Lines and crossed lines extending beyond the symbol frame may become confused in the map clutter of similar features, particularly in urban maps and satellite photographs.
- With only two symbols in the set, significant overlapping would be required before discrimination is lost between the two symbols.
- No affiliation information is provided.

Canada: This symbol set included all three echelons and a wide range of officer and enlisted roles.

- The use of circles with no in-fill to indicate officers departs from APP-6A conventions of rectangles with light blue in-fill. The enlisted symbols conform to the rectangular shape but lack in- fill colour. This lack of in- fill colour may make the symbols less discriminable against map backgrounds.

- Lines and crossed lines extending beyond the symbol frame are used to denote role and may become confused in the map clutter of similar features, particularly in urban maps and satellite photographs.
- Overlapping these soldier symbols would obscure echelon and, in some cases, role with only minor overlapping on the vertical lines outside of the symbol frame.
- No affiliation information is provided.

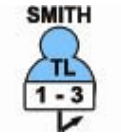
Netherlands: The Netherlands proposed a single symbol shape to represent the Section/Squad and then used an interior icon (i.e. number) to identify the role of each soldier.

- The use of a rectangular shape, a light blue in-fill, and interior icons conforms to APP-6A conventions.
- Since all symbol information is retained within the in-filled frame of the symbol we do not expect any issues in discernability against different map backgrounds.
- With only one echelon represented we do not know how this concept could be extended to represent other echelons and roles.
- No affiliation information is provided.

Switzerland: Only four symbols were included in this set: Company, Platoon, and Section Commanders, and soldier.

- The use of circles with no in- fill, no interior icons, and L-shaped lines does not conform to APP-6A conventions of rectangles with light blue in-fill and interior icons.
- While all three echelons are represented we do not know how this concept would be extended to represent other enlisted roles.
- Lines and crossed lines extending beyond the symbol frame may become confused in the map clutter of similar features, particularly in urban maps and satellite photographs.
- Reducing resolution resulted in line drops that reduced our ability to discern echelon and role.

- Overlapping these soldier symbols would obscure echelon and, in some cases, role with only minor overlapping on the vertical lines outside of the symbol frame.
- No affiliation information is provided.



U.S. Army: Only two symbols were included in this set: Team Leader and soldier (automatic rifleman).

- This symbol concept employs a complex torso shape over a small rectangle with the soldier's name displayed above the symbol frame, a two-letter designation for role in the torso, and unit affiliation numbers in the small rectangle.
- The torso shape is in-filled with light blue and the small rectangle is in-filled in white so we can say that the design partially conformed to APP-6A conventions.
- The complex shape of the torso reduces the available in-fill area and limited the available space for the interior text for role. Since the torso area is the only coloured in-fill it may become more difficult to discern different threat affiliation colours at smaller symbol sizes.
- The use of the soldier's name above the symbol frame effectively reduces the size of the symbol frame and the associated text size for role and affiliation.
- Symbol discriminability diminishes noticeably when it is reduced in size or displayed at lower resolutions.
- Since only one echelon is represented we do not know how this concept would represent the complete range of echelons and roles required.
- Text outside of the symbol frame may become confused in the map clutter of similar features, particularly in urban maps and satellite photographs. We found that the soldier name above the symbol was easily obscured in high-density urban satellite photographs. This is particularly likely for those soldiers with long last names.
- Affiliation information is provided.

U.S. Marine Corps: This symbol set included all three echelons and a wide range of officer and enlisted roles.

- Officers are represented by circle symbols with light blue in-fill, which departs from the APP-6A rectangle "Land" convention, whereas the enlisted symbols above the squad level conform to the rectangular shape.

- Lines and crossed lines extending beyond the symbol frame were used to denote role and echelon, and may become confused in the map clutter of similar features, particularly in urban maps and satellite photographs.
- Overlapping these soldier symbols would obscure echelon and, in some cases, role with only minor overlapping on the vertical lines outside of the symbol frame.
- The close proximity of the crossed lines to denote echelon became more difficult to discern at smaller symbol sizes and lower resolutions.
- No affiliation information is provided.

LCG1 Proposed: This symbol set includes all three echelons and wide range of officer and enlisted roles.

- All roles were represented by circle symbols with light blue in-fill, which departs from the APP-6A rectangle "Land" convention.
- Lines and crossed lines extending beyond the symbol frame are used to denote role and echelon, and may become confused in the map clutter of similar features, particularly in urban maps and satellite photographs.
- Overlapping these soldier symbols would obscure echelon and, in some cases, role with only minor overlapping on the vertical lines outside of the symbol frame.
- The close proximity of the crossed lines to denote echelon became more difficult to discern at smaller symbol sizes and lower resolutions.
- With the exception of the soldier symbol, enlisted roles are indicated with one or more diagonal lines. Discerning between 1, 2, and three partial or complete diagonal lines became difficult when the symbol sizes or display resolution was reduced.
- No affiliation information is provided.

A summary of this information is provided in the table below**.** A question mark in a cell indicates that the condition was partially satisfied, or could be satisfied without conducting lab trials.

Table 1: Summary of the results of the heuristic evaluation

Source and Number in Set	Conforms to APP 6A conventions	All echelons and roles represented	Affiliation represented	Discriminable against map background	External elements discriminable from worst case map background	Resists degradation in clutter and overlap contexts	Resists degradation at reduced szie and resolution
Belgium (2 symbols)	X	X	X	X	X	?	?
Canada (8 symbols)	?	✔	X	?	X	X	✔
Netherlands (1 symbol)	✔	?	X	✔	**NA**	✔	✔
Switzerland (4 symbols)	X	?	X	X	X	X	X
U.S Army (2 symbols)	?	?	✔	✔	X	X	X
USMC (7 symbols)	X	✔	X	✔	X	X	X
LCG1 (10 symbols)	X	✔	X	✔	X	X	X
Proposed New Set see Section 4.2 (8 symbols)	✔	✔	✔	✔	**NA**	✔	✔

Legend: ✔ - Complies, ? – Partially complies, X – Does not comply.

4.1.2 Overall Results

Criterion scores were summed to generate a total score (out of a possible 95 points), as a measure of general goodness-of-fit to the analytical framework (Figure 2).

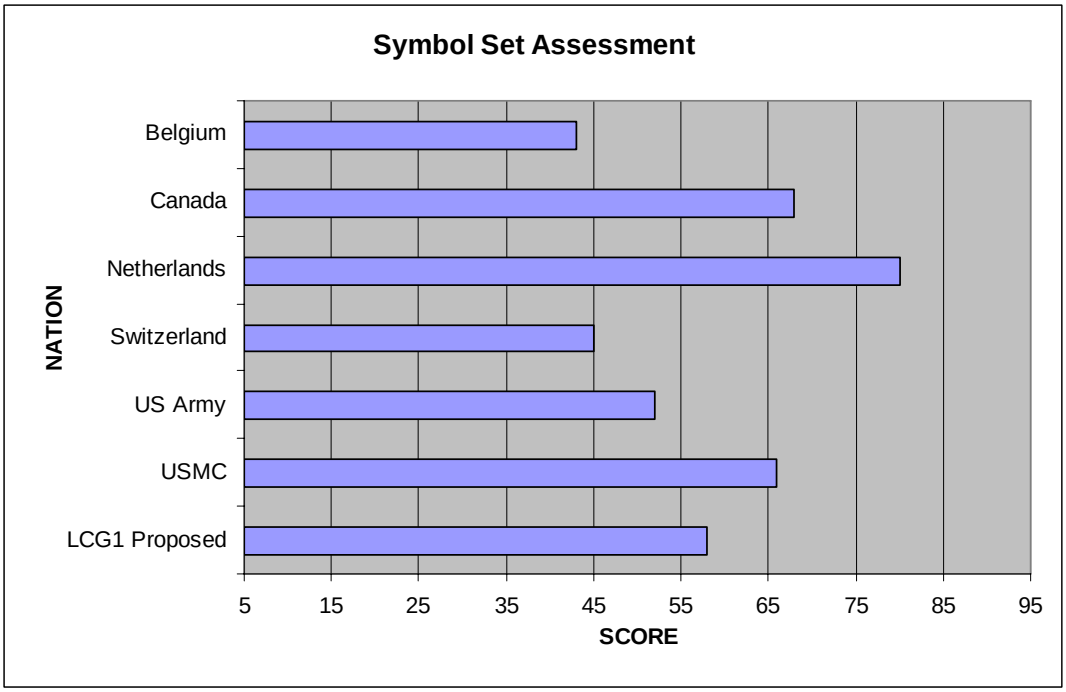


Figure 2: Total Symbol Set Score

Taken at face value, the Netherlands symbol set scored highest by complying with APP-6A design principles and by providing a relatively simple design concept. However, while demonstrating symbol characteristics that were successful in the analytical framework, the Dutch design does not address the more significant challenge of adapting their concept for different echelons and roles up to Company level. Only three symbol sets provide a reasonably complete set of roles and echelons (i.e. Canada, USMC, and LCG1 Proposed) and only the U.S. Army symbol set included affiliation. Therefore the use of a total score may not provide a fair comparison between these complete and incomplete sets. However, lessons can still be learned from the strengths and weaknesses of each symbol set when considering the design of any new set.

4.2 New Symbol Concept

Review of the scoring results of the analytical framework suggests that there is scope for developing a new symbol concept. The following section proposes a new example symbol set that meets these criteria; and a description of the design rationale for the new concept. Possible variations to this concept are also discussed.

4.2.1 New Symbol Set

The following symbol set was designed according to these design criteria.

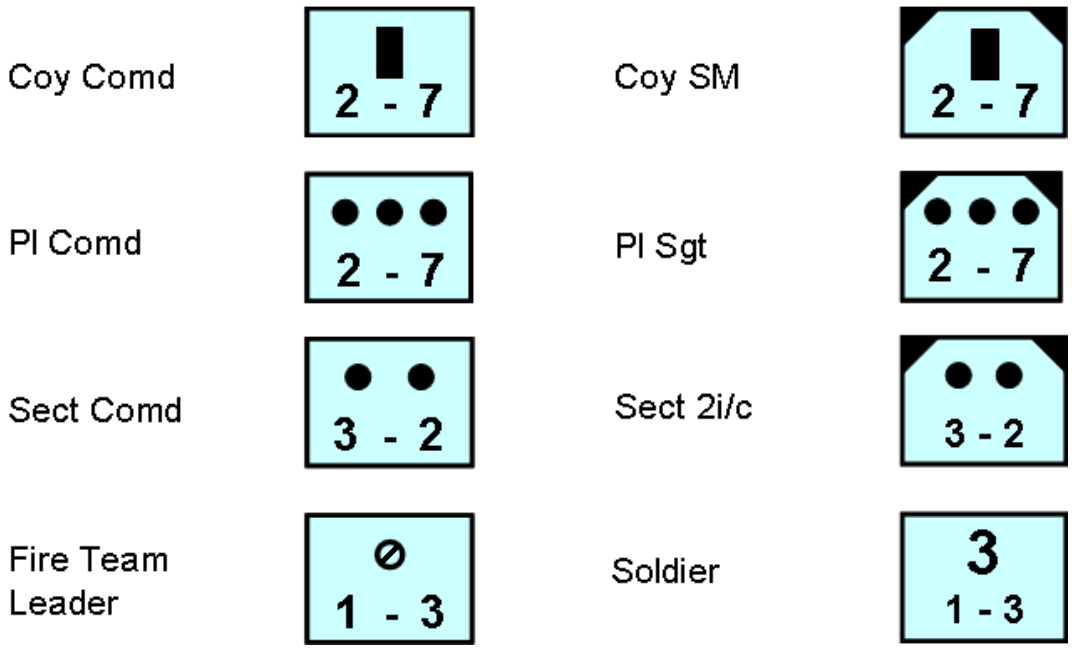


Figure 3: New Symbol Concept

4.2.2 Design Rationale

The new symbol concept (Figure 4) can be explained by the following design rationale.

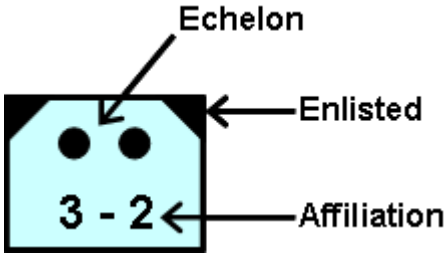


Figure 4: Symbol Breakdown

1. Symbol Shape and in-fill: A rectangular symbol shape with a clear frame border and light blue in-fill as per APP-6A.

2. Role: Commanders are denoted by a regular frame while enlisted 2 i/c soldiers are denoted by the angled corners. In sourcing a way to denote enlisted positions we consulted rank insignia for a range of NATO nations (Annex B). Characteristic of most enlisted rank insignia is a chevron or angled tabs. For this reason we have angled the corners of the enlisted symbols to give the illusion of a chevron over the blue in-fill.

3. Echelon: Echelon is represented using the same convention as APP-6A, as indicated in Figure 5 below.

Indicator	Description
Ø	Team/Crew
•	Squad
••	Section
•••	Platoon
|	Company

Figure 5: NATO APP-6A Echelon Icons

4. Affiliation: Unit affiliation is indicated by the convention of "sub-unit of unit". For example, *One Section* of *Three Platoon* would be denoted as 1-3. Soldier members of a Section/Squad, not including the Section Commander or 2 i/c, would be denoted by a single number to reflect their position.

5. Clutter and Overlap: All soldier identity information is contained within the symbol frame to avoid any loss of discernability due to background clutter and to minimize any information loss due to symbol overlapping.

6. Size/Resolution: The symbol design is able to be reduced in size and resolution without the loss of role and echelon identity.

The new symbol set concept design was scored by the authors with the analytical framework (Figure 6) and generated a near-perfect score. The design only lost points for discernability of affiliation at the lowest resolutions and sizes, suggesting that some fine tuning of numeric text fonts is required. See also, Table 1, which summarizes the high conformity of this design to the heuristic criteria.

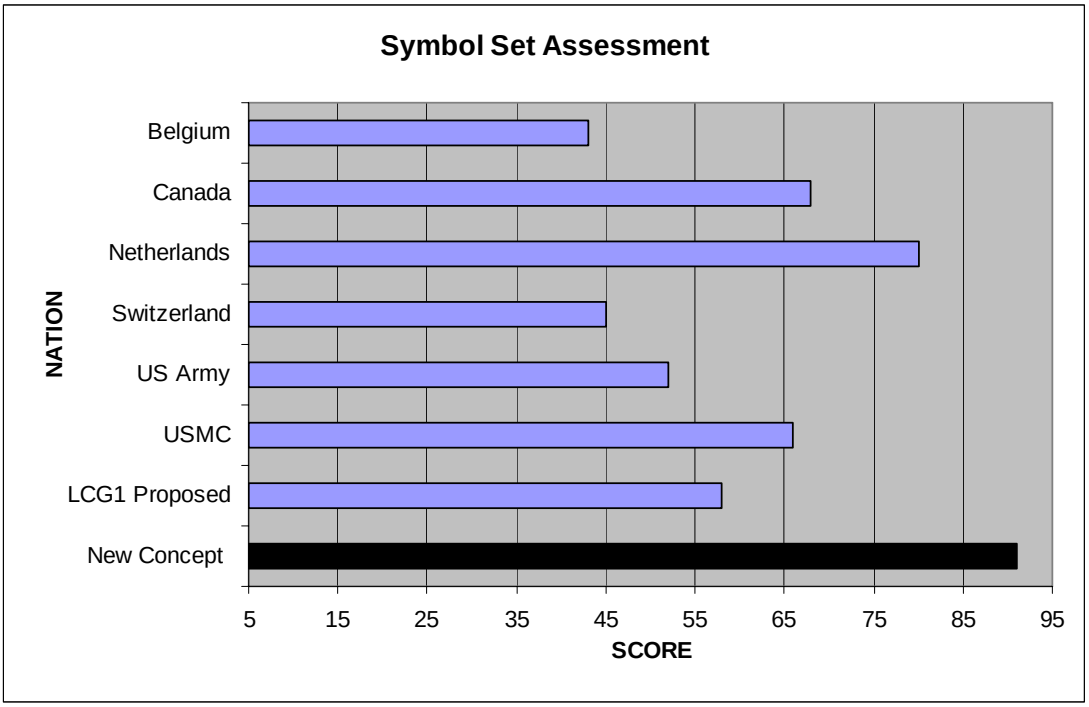


Figure 6: New Symbol Total Score

4.2.3 Potential Variations

There are several variations that could be pursued with a single symbol concept. An example variation of the new symbol concept is shown below (Figure 7). In this case the echelon indicator was aligned vertically to provide the space necessary to enlarge the numeric text denoting the Platoon affiliation. This would allow further downsizing of the symbol or greater degradation by limitations in device resolution without compromising echelon information. Such variations require user-centered testing and evaluation to determine if any particular variation is superior to another with respect to legibility and comprehensibility.

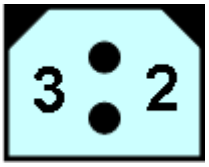


Figure 7: Alternative Symbol Configuration

5 Phase II: Test and Evaluation

5.1 Objective

This section outlines the plan to address the Statement of Work (SOW), item (f), which reads:

> *"Develop a proposal for a more systematic evaluation of the proposed soldier system tactical graphics and operational symbols for representing individual soldiers on the basis of:*
> - *discriminability amongst symbols that are likely to appear on the same display*
> - *learnability and intuitiveness*
> - *visibility against map backgrounds*
> - *suitability for use on handheld devices*
> - *visibility on or while using NVGs and thermal vision systems.*
>
> *It is anticipated that the proposal will include recommendations for both laboratory studies using naive observers and field studies. The proposal should discuss both the experimental environment and the type of studies that would be run on that environment."*

5.2 Approach

The approach to this work has been shaped by various standards and guidelines (including NATO App 6-A) together with HSI®'s extensive experience in test and evaluation of military C4I systems.

EG Standard 201 379 V1.1.1. provides guidelines for creating, selecting and evaluating graphical symbols within the telecommunications sector. It highlights the relevant human factors issues, provides guidance about the appropriate use of symbols and helps to assure that symbols produced meet the quality demanded by standards bodies. It recommends the following criteria for evaluating a selected symbol set, which map closely the SOW objectives.

- Comprehensibility – the ease with which the meaning of the symbol is understood
- Discriminability – the ease with which a given symbol can be distinguished from other symbols that might occur in close spatial, temporal or contextual proximity.
- Learnability – the ease with which the meaning of a symbol can be recalled after it has been understood
- Legibility – the ease with which the graphic detail of a symbol can be discerned[4].

[4] We take this to mean the ability to discriminate from the map background

- Recognizability – the ease with which it is possible to identify a symbol based on previous experiences with the same or similar types of symbols.

Because of the large number of potential independent variables (e.g. display device, display resolution, symbol size, map background, map complexity, symbol plot density, ambient viewing conditions and number of symbols), as well as potentially five different measurement metrics, it is impractical to consider a parametric design that examines systematically all levels of all variables. Instead we propose a methodology that progressively narrows down the candidate variables through three main stages of experimentation, while still maintaining the goal of identifying the strongest design candidates and the boundary conditions for acceptable performance. These stages are as follows:

5.2.1 Laboratory experimentation

This is to be conducted at HSI®'s own testing facility. In this phase we would study the discriminability and legibility of all design elements of each symbol set against a variety of map backgrounds at two resolution levels and two symbol sizes only, and investigate effects of clutter and plot density. A standard high resolution computer display will be used to simulate laptops, hand held displays, NVGs and rifle sights.

As a result of this process, performance metrics (see below) will guide which subset of display symbology will be taken forward for phase (ii), field testing.

5.2.2 Field testing

The goal of field testing will be to evaluate how the symbols perform in a simulation of actual operational conditions that will provide quantitative data for legibility, discriminability and recognition metrics. For example, soldiers will be asked to perform tasks such as: *who is at map co-ordinate x,y,; find the 2i/c of section.....*. This component of testing will also take into account environmental variables, such as the level of ambient lighting and lighting direction.

In addition, subjective measures, using validated ratings scales will be used to assess the comprehensibility, learnability and usability of the symbol sets from an experienced soldier's perspective.

5.2.3 Final testing and concept design refinement

As a result of the field trial, there will likely be some results that will suggest further experimentation and refinement of the design approach. Therefore, it is proposed that a further round of testing may take place again in the laboratory to further refine the symbol set and to evaluate any symbol modifications under conditions suggested by the field trial.

The goal of this phase is to take any lessons learned from the field testing, address any residual un-answered issues and finalise the design for a recommended symbology set.

The primary tasks for each phase of the study, as far as can be determined in advance, are outlined below.

5.3 Phase I: Laboratory study

The major tasks for this phase will be:

- Rendering the candidate symbols sets, using graphical software, in the appropriate resolution and size for each display medium (i.e. display device)
- Developing/ adapting software to conduct experimental tests
- Preparing and obtaining approval for a Research Ethics Protocol
- Recruiting and scheduling subjects
- Developing required training materials (PowerPoint presentations)
- Developing training criteria
- Developing an appropriate experimental design for the number of trials required to generate the appropriate number of data points for reliability
- Determining and implementing methods for data capture and storage
- Conducting study
- Analyzing data
- Reporting

Each of the above (minus the last two items) will be documented in detail and will be written in the form of **a test plan** to be submitted as a first deliverable to the scientific authority for approval and comment. The data analysis and associated report will comprise the second deliverable.

5.3.1 Symbol sets

Representative symbols from the existing national symbol sets as well as the new symbol set proposed by the contractor during phase 1 will be used. Based upon the results of the heuristic evaluation, it is anticipated that no more than three of the existing national symbol sets will be evaluated. Up to five symbols, where available, (representing echelon and role distinctions) will be presented for each of the symbols sets.

5.3.2 Contextual variables

The following variables will be studied: **map background** -uniformity (3 levels) and regularity (two levels, for example, built-up urban areas versus more natural rural areas**);** and **contact plot** density (two levels)

5.3.3 Display resolution

It is anticipated that resolutions corresponding to those typically found with laptops, portable hand held devices, night vision goggles and rifle sights will be simulated.

5.3.4 Performance metrics

The primary metrics to be used will be:

- Legibility. recognition and discrimination accuracy (percent correct and the d' sensitivity metric) and error rates
- Recognition and discrimination response time.

5.3.5 Experimentation Environment

For the laboratory testing environment we recommend leveraging the RESOLVE software developed for DRDC Toronto by Array Systems Computing (Figure 8). Using this environment we can evaluate the suitability of different symbol set designs with a wide variety of map and satellite photograph backgrounds. This software provides an auto-configurable means of changing screen resolution and anti-aliasing capabilities to simulate a wide range of possible soldier system display devices. Experimentation controls provide effective randomization and counter-balancing of conditions, control of target symbol presentation location, orientation, and timing, and logging of subject responses to target presentation.

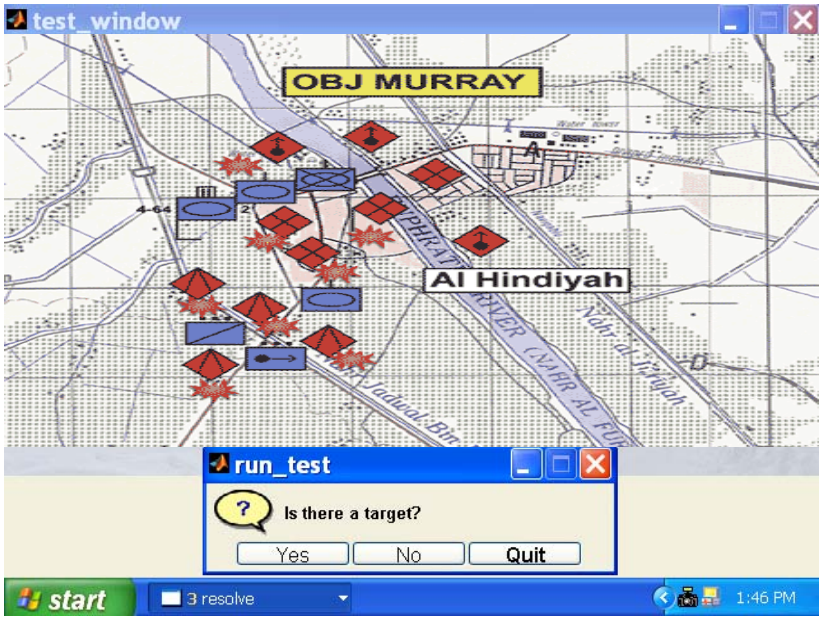


Figure 8: RESOLVE Software Environment

5.3.6 Subject requirements

The number of subjects to be tested at this stage is expected to be a minimum of ten, providing that each can perform multiple test sessions in a complete block repeated-measures design. Assuming a maximum of 2 hours per test session, we anticipate that approximately 40-60 test sessions may be required.

5.4 Field trials.

To review, the results of the laboratory study will allow HSI® to eliminate specific symbol sets from further evaluation. After consultation with the Scientific Authority, the most promising candidates based upon laboratory testing will then be selected for inclusion in the field trial.

The major components of the field trial would be identical to the steps outlined in the phase I laboratory study with the following additions:

- Liaison with army point of contact for scheduling trials and arranging for trial participants
- Development and testing of technology to display maps and symbology on soldier portable devices and capture data
- In consultation with Army SMEs, specification of suitable map-based operational tasks that will comprise the means for generating field data
- Development of questionnaires/rating scales for learnability, comprehensibility, usability, preference
- Determining a design methodology that will adequately sample the required environmental conditions (e.g. daylight, dusk and night, lighting direction, direct sunlight and overcast conditions).
- Travel and logistics associated with trial conduct

The development of a test plan which incorporates the above will form the third deliverable.

5.5 Final laboratory trial

The details of this final trial cannot be determined with precision at this point in time. However, we are including this as a place-holder to address any unanticipated, residual issues arising from the field trial. These could include: re-design and re-testing of symbology to enhance field performance, re-testing under simulated conditions that could not be achieved in the field, re-testing with NVGs and rifle sights based on lessons learned in the field.

The decision to proceed with this final stage of testing would be based upon discussions with the scientific authority, once specific objectives have been outlined in a test plan.

5.6 Summary of deliverables

1. Trial Plan for Phase I- Laboratory Study
2. Report of Phase I trial outcome
3. Trial Plan for Phase II- field study
4. Report of Phase II trial outcome and recommendations and trail plan for Phase III
5. Report of Phase III trial and final recommendation for final symbol design

6 Discussion

The aim of this study was (i) to review existing symbol sets from contributing NATO nations against standards for Land operations, human factors, and adaptability to a range of digital displays, and (ii) to develop a symbology set if required to meet these standards. The review of existing symbol sets and the development of a new symbol set are discussed below, as well as software considerations for symbol design and presentation in future soldier systems.

6.1 Existing Symbol Sets

The review of existing symbol sets, provided by LCG1, against the heuristic framework indicated that they generally fell short of the ideal. Most symbol sets failed to conform to fundamental APP-6A design requirements for symbol shape, in-fill colour, and echelon distinction. Many symbol sets also employed lines, t-crosses, and text outside of the symbol frame to indicate echelon, role, and identity. These design features were subject to problems of detection and identification due to confusion with highly textured map and satellite imagery backgrounds and symbol overlap. As well, such details of double line, text, and complex shapes lost their discernability when reduced in size or display resolution, thereby reducing the ability to recognize the symbol meaning.

Several nations only provided limited-scope, initial efforts that expressed their national concept. While useful for expressing a concept, these designs did not have to meet the challenge and rigors of adapting the concept to the required range of roles and echelons from Company and below. In these cases, a concept might score better than it would have if the complete scope of symbol dimensions were to be developed. For this reason, any future collation and review of national soldier symbology should set out a standard list of soldier symbols, identifiable by role and echelon to ensure that each candidate symbol set can address the complete range of complexity of information required at the Company level and below.

6.2 New Symbol Set Concept

A new symbol concept was developed to conform to APP-6A; to include identifiers for role, echelon, and affiliation; to remain discernible (i) in the presence of highly textured backgrounds, (ii) when symbols are tightly clustered and (iii) when reduced in size or display resolution. Although these goals were largely met we believe the following efforts are necessary to completely fulfil them.

6.2.1 Resampling vs Bottom up Design

To evaluate the robustness of the different symbol designs to size and resolution reductions we selected somewhat arbitrary sizes and pixel grids to reflect the range of possible display configurations in soldier systems equipment. We digitally reduced each symbol resolution into each grid using a re-sampling technique that is typical of most graphical display processing. This re-sampling process endeavoured to make the best

match of the original symbol to the new, lower resolution grid by adjusting the tones and gray-levels by image interpolation in an effort to retain the general “look” of the symbol.

Another approach to symbol design would be to identify the smallest meaningful resolution and build the symbol design from the bottom up. In this way a coherent, discernible symbol would exist at the lowest resolution that could then be up-sampled into higher resolution grids for higher resolution displays. In many cases, this would amount to a fine tuning exercise of an existing concept to improve discriminability of line spacings, text features (i.e. font, size), and icon details.

We plan to discuss these options with the Scientific Authority to determine which approach to take in the test and evaluation trial.

6.2.2 Operational Symbology

All of the symbol sets reviewed and developed in this study focused exclusively on soldier symbology and not operational icons that show function. The example in Figure 9 shows an automatic rifle icon embedded in the new symbol concept. Prior to confirming any future NATO symbol set, the new symbol design must be evaluated to ensure that all operational icons, necessary for Company operations, can be adequately discerned.

Figure 9: Example Operational Symbol (automatic rifle)

6.3 Software Considerations

The design of any new soldier system symbology can and should be influenced by the hardware and software capabilities of future soldier system computers. Symbol design need not be limited by a single design image. The content, type, and style of information presentation can be modified by soldier system software to enhance the effectiveness of symbol presentation to match the specific information needs of each user according to their role, the mission, the lighting conditions, etc. Intelligent software solutions can also be used to manage the display interface to address issues with screen clutter, clustering of symbols, conspicuity, and information display management. Several of these software-related issues are discussed below.

6.3.1 Conspicuity

There is much that can be done with software to make symbols more conspicuous in the soldier display. Specific symbols can be made to be more noticeable by increasing their size relative to other symbols, typically by minimizing the other symbols to expose more of the background map. Alternatively, all symbols could be minimized in size until a soldier selects a particular symbol (e.g. by cursoring over it or touching the symbol on the screen) to temporarily expand it and/or identity information on the screen.

The contrast between symbols of interest and the map (or satellite photograph) background can also be enhanced to improve symbol detection and readability of identity information. Software could ghost a high-contrast, semi-transparent border around a specific symbol, make it appear to stand off the screen, and so on to improve the detection of particular symbols of interest. Similarly, additional colour or brightness coding could be used to make certain symbols stand out more against the background and distinguish them more clearly from other symbols on the screen. Lastly, animation could be used to further reduce detection/recognition times. Since the eye is drawn to motion or temporal change, a critical symbol of interest could be set to flashing or have a feature that appears to move or pulse.

These sorts of software features could be standardized according to particular roles and echelons, to match general user needs, or they could be set by the user to address the specific needs of missions and operational conditions.

6.3.2 De-cluttering

Depending on the nature of a mission there could be a large number of symbols present on a screen at any one time. This clutter could seriously impede timely detection/recognition of symbols important to the user and obscure important background map information. As well, errors are more likely to be made by soldiers in high stress, high tempo situations when the information is needed most. Future soldier systems need to control this clutter in a way that better matches the information displayed to the information required by each individual user.

This suggests a user profile or user configurable means of filtering map display information. For example, a Section commander may need to see the members of his Section, his Platoon commander, the other two Section commanders in the Platoon, and

the weapons detachment whereas a Platoon commander may only want to see his Section commanders, weapons detachment, and his flanking Platoon commanders. In each case, the user needs and requirements for positional information are quite different for quite different reasons. The soldier system software needs to recognize these differences and provide a means for accommodating them to minimize symbol clutter.

6.3.3 De-clustering

Small-unit soldiering involves team tactics, techniques, and procedures that often place several soldiers in close geographic proximity. This will naturally result in the apparent clustering of the soldier symbology on the screen to the extent that the overlapping of symbols will obscure the number and identity of soldiers.

There are a number of possible software techniques for de-clustering overlapped symbols. A soldier could select a particular cluster of symbols (e.g. by cursoring over it or touching the cluster on the screen) to temporarily explode them into a tiled presentation or into a blossom array so that they can all be clearly viewed. Alternatively, the software can employ methods of aggregation and disaggregation of co-located symbols.

6.3.4 Aggregating/Disaggregating

There are 35 or more soldiers in each Platoon. Displaying each soldier on a map display can potentially overwhelm the screen with clutter and obscure much of the usable background map. While it is useful at times to be able to see all soldiers in an area of interest, most clusters of soldiers represent discrete tactical groupings that can be effectively aggregated into a single symbol; often under the leader of that tactical grouping. This could be partially addressed by a software system that could aggregate and disaggregate symbols according to user-specific rules. For example, aggregation/disaggregation could be based on the zoom level (map scale) selected by the user. When zoomed close in to the map (e.g. soldier's area of influence), all soldier symbols would be displayed. As the soldier zoomed out (e.g. soldier's area of interest) their Section of soldiers would be displayed and only the leaders of the other Sections, the Platoon commander, and the weapons detachment. Zooming out again may only display your Section and Platoon commanders, flanking Platoon commanders, and Company commanders, and so on. The most appropriate map scale points at which the transition takes place would need to be determined by user test and evaluation.

6.3.5 Internal v External Users

The requirements for soldier identity information for users within a team (e.g. Section) will be quite different to those users outside the team (e.g. flanking Platoon commander). Within your Section you can identify your members with a simple, single number and minimize symbol size and screen clutter. However, the flanking Platoon commander would be confused by all Section members with all Platoons using simple, single numbers as there would be three duplicates in each Platoon for each position and he wouldn't know who was a member of which Section in which Platoon. For this reason, the Platoon commander's system must display Section affiliation. The Company commander would also want to see echelon information, and so on. The point here is that symbol identity information can be scaled relative to each user's need for information to ensure that

unnecessary information, and associated symbol complexity and screen clutter, is avoided whenever possible. This applies within a nation and across inter-operable NATO nations.

Would you design a symbol differently if you knew these software features were available to you? We believe that you would and that this could enable profound improvements and flexibility in the design and display of soldier symbology. This may be out of scope for LCG1 but we believe that it is reasonable to consider for the specific-to-nation, internal display of symbology information.

6.3.6 Conclusions and Recommendations

A heuristic analysis was undertaken in this study to evaluate candidate symbol sets and to develop a new set if necessary. The symbol set designs provided by LCG1 were judged to be inadequate, against the requirements in the heuristic analysis. While some designs appeared promising, most did not address the true complexity of the range of roles, ranks, echelons, and affiliations in a Company-sized organization. A new symbol set was designed to better satisfy the requirements of the heuristic analysis. While satisfying the heuristic, we do not yet know how effective the design will be across all types of map and satellite photographic backgrounds with the typical clustering and disposition of soldier symbols in small-unit operations.

While using a heuristic to drive a development effort is useful in defining concepts, it lacks the precision and user involvement necessary to confirm detectability, learnability, discernability, usability, legibility, etc. We strongly recommend that any candidate symbol set be taken through a rigorous series of laboratory and field testing with representative users, undertaking representative tasks in representative conditions to validate and fine tune the design.

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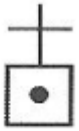
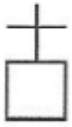
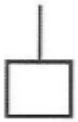
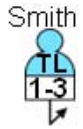
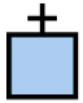
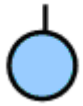
ANNEX A

SOLDIER SYMBOL SETS

ANNEX A

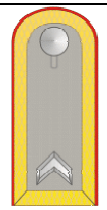
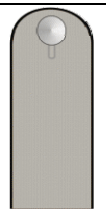
COUNTRY	ROLE									
	Company Commander	**Company 2 i/c**	**Gunnery Sergeant**	**Company Quartermaster Sergeant**	**Platoon Commander**	**Platoon Sergeant**	**Section Commander**	**Section Commander 2 i/c**	**Fire Team Leader**	**Soldier**
Belgium							 Section Chief			 Soldiers
Canada			 Warrant Officer	 Master Warrant Officer	 Platoon Commander	 Platoon Warrant	 Section Commander	 Corporal		
Netherlands							 Sergeant	 Corporal		 Private
Switzerland	 Unit Leader				 Platoon Leader		 Group Leader			 Soldier

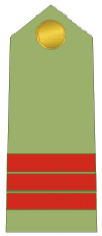
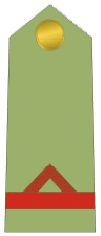
ANNEX A

COUNTRY	ROLE									
	Company Commander	**Company 2 i/c**	**Gunnery Sergeant**	**Company Quartermaster Sergeant**	**Platoon Commander**	**Platoon Sergeant**	**Section Commander**	**Section Commander 2 i/c**	**Fire Team Leader**	**Soldier**
United States Army										
United States Marine Corps										
LCG1 Proposal										

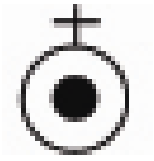
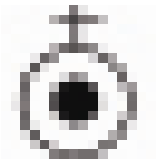
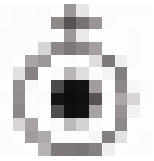
NATO RANK INSIGNIA

ANNEX B

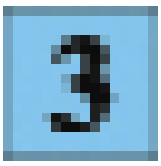
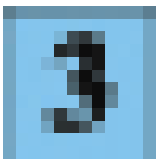
COUNTRY	Army Rank								
	Major (OF-3)	Captain (OF-2)	Lieutenant (OF-1)	Warrant Officer (OR-7 –9)	Master Sergeant (OR-7)	Sergeant (OR-6)	Corporal (OR-4)	Private First Class (OR-2)	Private (OR-1)
Belgium									
Canada									no insignia
Netherlands									
Germany									

COUNTRY	Army Rank								
	Major (OF-3)	Captain (OF-2)	Lieutenant (OF-1)	Warrant Officer (OR-7 –9)	Master Sergeant (OR-7)	Sergeant (OR-6)	Corporal (OR-4)	Private First Class (OR-2)	Private (OR-1)
Spain									
Switzerland									
United States									no insignia

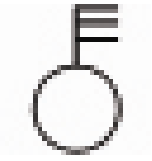
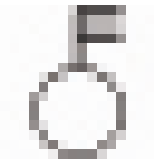
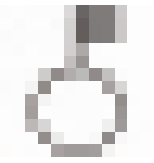
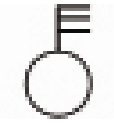
SYMBOL SIZE/RESOLUTION MATRICES

Canada		Resolution (pixels)			
		64X64	32X32	16X16	12X12
Size (mm)	20X20				
	15X15				
	10X10				
	5X5				

Netherlands

Size (mm)	Resolution (pixels) 64X64	32X32	16X16	12X12
20X20				
15X15				
10X10				
5X5				

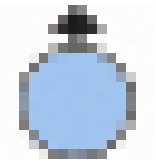
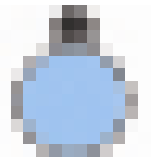
Switzerland

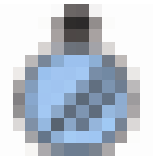
Size (mm)	Resolution (pixels) 64X64	32X32	16X16	12X12
20X20				
15X15				
10X10				
5X5				

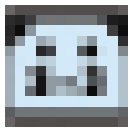
U.S. Army

Size (mm)	Resolution (pixels)			
	64X64	32X32	16X16	12X12
20X20				
15X15				
10X10				
5X5				

USMC

Size (mm)	Resolution (pixels) 64X64	32X32	16X16	12X12
20X20				
15X15				
10X10				
5X5				

LCG1 Proposed		Resolution (pixels)			
		64X64	32X32	16X16	12X12
Size (mm)	20X20				
	15X15				
	10X10				
	5X5				

New Symbol		Resolution (pixels)			
		64X64	32X32	16X16	12X12
Size (mm)	20X20				
	15X15				
	10X10				
	5X5				

ANNEX D

SYMBOL SET SCORING TABLES

Military Domain - 1			
All symbols within the set conform to a rectangular “ground” shape as per the aspect ratios of MIL-STD-2525C (1:1, 1:1.5). *1- does not conform, 3 – conforms to shape but not aspect ratio, 5 – conforms for shape and aspect ratio.*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	1	Yes, circles to squares	
Canada	2	Yes, circles to squares but conflicts with existing symbols. Requires change to entire set.	Most do not conform, with the exception of enlisted ranks.
Netherlands	5		
Switzerland	1	Yes, circles to squares	
US Army	3		Rectangular base complies but complex “torso” shape does not.
USMC	2	Yes, circles to squares but conflicts with existing symbols. Requires change to entire set.	No most do not conform, with the exception of Gunnery Sgt and Pl Sgt.
LCG1 Proposed	1	Yes, circles to squares.	
New Concept	5		

Military Domain - 2			
Symbols have an appropriate frame border width. *1 – no frame, 3 – frame does not clearly indicate the symbol, 5 – clearly indicates the symbol*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	2	Can be easily modified	
Canada	3.5	Can be easily modified	
Netherlands	5		
Switzerland	4		
US Army	5		
USMC	5		
LCG1 Proposed	5		
New Concept	5		

Military Domain - 3			
Symbols use both shape and fill colour to indicate battle dimension. *1 – no, 3 – one option only, 5 - both.*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	1	Yes, fill can be added and shape changed.	
Canada	1	Yes, fill can be added and shape changed.	
Netherlands	5		
Switzerland	1	Yes, fill can be added and shape changed.	
US Army	5		
USMC	5		
LCG1 Proposed	5		
New Concept	5		

Military Domain – 4			
Symbol friendly interior elements can be recognizable at the smallest expected symbol size. *1 – not recognizable, 3 – partially recognizable, 5 – fully recognizable*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	NA		No interior elements
Canada	5		
Netherlands	5		
Switzerland	NA		No interior elements
US Army	3		At smaller sizes the “torso” addition would result in greater reduction of font sizes compared to a rectangle alone.
USMC	3	Could be modifiable by extending size of symbols to extend bars.	At smaller sizes there is confusion between circle symbols and square symbols.
LCG1 Proposed	2	Could be modifiable by spacing out lines further to use available space.	At smaller sizes there is confusion between diagonal line elements and between T lines.
New Concept	5		

Military Domain – 5			
Symbol interior elements can be recognizable at the smallest expected symbol size for the following affliliations: Red (Hostile and suspect), yellow (unknown) and green (neutral). *1 – not recognizable, 3 – partially recognizable, 5 – fully recognizable.*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	NA		No interior elements
Canada	5		
Netherlands	5		
Switzerland	NA		No interior elements
US Army	3		Affiliation could be more difficult to discriminate as less than 50% of symbol uses colour.
USMC	3		
LCG1 Proposed	2	Could be modifiable by spacing out lines further to use available space.	At smaller sizes there is confusion between diagonal line elements and between T lines.
New Concept	5		

Military Domain – 6			
The frame indicates the location status (actual vs planned) of the soldier at the smallest expected symbol size. *1 – no status, 3 – frame does not clearly indicate status, 5 – clearly indicates status*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	5		
Canada	5		
Netherlands	5		
Switzerland	5		
US Army	3	Complex shape may offer a range of modification options.	Complex contours make dashed line harder to discriminate
USMC	5		
LCG1 Proposed	5		
New Concept	5		

Military Domain – 7			
Symbols are universally consistent with NATO echelon conventions. *1- not consistent, 3 – partially consistent, 5 – fully consistent.*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	1		Only one echelon provided.
Canada	1		Not consistent.
Netherlands	1		No echelon indication.
Switzerland	4		Unit size shown by lines and not dots.
US Army	1		Unit size is shown by numbers alone.
USMC	2		Unit size shows echelon but not consistent with NATO.
LCG1 Proposed	2		Unit size shows echelon but not consistent with NATO.
New Concept	5		

Human Factors – 1			
Role symbols are discriminable from each other. *1- not discriminable, 3 – somewhat discriminable, 5 – fully discriminable.*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	3		Incomplete, only two roles shown
Canada	5		
Netherlands	4		Font style will be important for discriminating numbers
Switzerland	3.5	Could be improved with more line separation	Choice of lines to discriminate role could compromise discimination at smallest size. No enlisted roles were provided beyond soldier.
US Army	2		Discrimination requires reading relatively small text which compromises discrimination at small sizes.
USMC	3.5	Yes	Discriminable at full size but some confusions arise when size is reduced – particularly Coy and Pl Comds.
LCG1 Proposed	3	Yes	Discriminable at full size but some confusions arise when size is reduced – particularly Coy and Pl Comds.
New Concept	5		

Human Factors – 2			
Symbols maintain their integrity when clustered together (not overlapped). *1- no integrity, 3 – medium integrity, 5 – high integrity*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	5		With only two symbols provided there is little source of confusion.
Canada	5		
Netherlands	5		
Switzerland	4		Multiple lines in symbols can be confused when clustered.
US Army	3		High density of information and lack of discriminability between symbols. High clutter
USMC	5		
LCG1 Proposed	5		
New Concept	5		

Human Factors – 3			
Symbols convey required information with fewest elements. *1- many elements, 3 – several elements, 5 – few elements*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	5		
Canada	5		
Netherlands	5		
Switzerland	4.5		
US Army	3	Less info could be used	Many elements are used to convey information.
USMC	4.5		
LCG1 Proposed	3		Gny and Coy Sgt symbols require too many elements to convey.
New Concept	5		

Human Factors – 4			
Symbols can be replicated easily?(ie drawn by hand on paper) *1- very difficult, 3 – somewhat difficult, 5 – not difficult*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	5		
Canada	5		
Netherlands	5		
Switzerland	5		
US Army	1		Considerable detail required with a complex shape, and several text elements.
USMC	4		
LCG1 Proposed	3		Gny and Coy Sgt symbols require too many elements to convey.
New Concept	4		

Human Factors – 5			
Symbols can be readily discernible from a temperate map background. *1- not discriminable, 3 – somewhat discriminable, 5 – fully discriminable.*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	2.5		No fill colour and much thinner border thickness would make these less discernable
Canada	3		No fill colour and thinner border thickness would make these less discernable
Netherlands	5		
Switzerland	3		No fill colour and thinner border thickness would make these less discernable
US Army	4		
USMC	4		
LCG1 Proposed	4		
New Concept	5		

Human Factors – 6			
Symbols can be readily discernible from an arid map background. *1- not discriminable, 3 – somewhat discriminable, 5 – fully discriminable.*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	2.5		No fill colour and much thinner border thickness would make these less discernable
Canada	3		No fill colour and thinner border thickness would make these less discernable
Netherlands	5		
Switzerland	3		No fill colour and thinner border thickness would make these less discernable
US Army	4		
USMC	4		
LCG1 Proposed	4		
New Concept	5		

Human Factors – 7			
Symbols can be readily discernible from highly textured map background (lines, buildings, etc). *1- not discriminable, 3 – somewhat discriminable, 5 – fully discriminable.*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	1		Symbols with long extensions outside the frame may be confused with lined map features. Thin border makes discernability difficult
Canada	2		Symbols with long extensions outside the frame may be confused with lined map features.
Netherlands	5		
Switzerland	1.5		Symbols with extensions outside the frame may be confused with lined map features.
US Army	3		External names, letters, and numbers could get lost in background clutter.
USMC	3		Symbols with extensions outside the frame may be confused with lined map features.
LCG1 Proposed	3		Symbols with extensions outside the frame may be confused with lined map features.
New Concept	5		

Human Factors – 8			
For discrete icons there is a clear gap between the icon and the surrounding border at the smallest usable size. *1- not discernible, 3 – somewhat discernible, 5 – very discernible*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	NA		No icon
Canada	5		
Netherlands	5		
Switzerland	NA		No icon
US Army	1	Gap could be increased but this would result in smaller text elements.	Insufficient gap between numbers and letters and the frame
USMC	4		
LCG1 Proposed	2		Inconsistent line lengths and angles
New Concept	5		

Human Factors – 9			
Symbol can accommodate worst-case overlapping direction without loss of discernability. *1- no overlapping, 3 – some overlapping, 5 – considerable overlapping*			
Nation	**Score**	**Modifiable?**	**Comments**
Belgium	4		NB only two symbols.
Canada	2.5		Vertical extensions above the frame can be overlapped or confused with map lines.
Netherlands	5		
Switzerland	2		Vertical extensions above the frame can be overlapped or confused with map lines.
US Army	4 for interior and 2 for exterior		Exterior elements (e.g. name) can be easily obscured by overlapping symbols.
USMC	2		Vertical extensions above the frame can be overlapped or confused with map lines.
LCG1 Proposed	2		Vertical extensions above the frame can be overlapped or confused with map lines.
New Concept	4		

Display Issues – 1

The symbols can be discriminated from each other for role (i.e. commander or 2 i/c) at smaller sizes and at lower resolutions?

Scoring indicates the proportion of 16 size/resolution matrix combinations that can be discriminated. Symbol sizes ranges from 20mm, 15mm, 10mm, and 5mm. Symbol resolution ranges from 64x64, 32x32, 16x16, and 12x12 pixels.

1- no combinations, 3 – 50% of combinations, 5 – 100% of combinations

Nation	Score	Modifiable?	Comments
Belgium	5		
Canada	5		
Netherlands	5		Easy to discriminate but symbol set only includes Section/Squad level.
Switzerland	NA		Only commander symbols provided, no 2 i/c symbols.
US Army	2		Role discrimination depends on readability of small text embedded in symbol.
USMC	5		Can easily distinguish circles from squares.
LCG1 Proposed	5		
New Concept	5		Chevron corners easy to discriminate.

Display Issues – 2

The Unit affiliation of symbols can be discriminated from each other at smaller sizes and at lower resolutions?

Scoring indicates the proportion of 16 size/resolution matrix combinations that can be discriminated. Symbol sizes ranges from 20mm, 15mm, 10mm, and 5mm. Symbol resolution ranges from 64x64, 32x32, 16x16, and 12x12 pixels.

1- no combinations, 3 – 50% of combinations, 5 – 100% of combinations

Nation	Score	Modifiable?	Comments
Belgium	NA		No affiliation shown.
Canada	NA		No affiliation shown.
Netherlands	NA		No affiliation shown.
Switzerland	NA		No affiliation shown.
US Army	1.5		Affiliation is indicated in small text that loses discriminability quickly at lower resolution and size.
USMC	NA		No affiliation shown.
LCG1 Proposed	NA		No affliliation shown.
New Concept	3	May be able to use a different type and size of font.	Heavy font loses discriminability at lower resolution.

Display Issues – 3

The echelon of symbols can be discriminated from each other at smaller sizes and at lower resolutions?

Scoring indicates the proportion of 16 size/resolution matrix combinations that can be discriminated. Symbol sizes ranges from 20mm, 15mm, 10mm, and 5mm. Symbol resolution ranges from 64x64, 32x32, 16x16, and 12x12 pixels.

1- no combinations, 3 – 50% of combinations, 5 – 100% of combinations

Nation	Score	Modifiable?	Comments
Belgium	NA		Only one echelon provided above soldier.
Canada	5		
Netherlands	NA		Only Section/Squad level provided.
Switzerland	3	Line spacing could be increased.	Line spacing loses discriminability at lower resolution.
US Army	1.5		Echelon is indicated in small text that loses discriminability quickly at lower resolution and size.
USMC	2	Gap between lines could be enlarged.	Double lines lose discriminability at lower resolution and smaller sizes.
LCG1 Proposed	2	Gap between lines could be enlarged.	Double lines lose discriminability at lower resolution and smaller sizes.
New Concept	5		

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(U) Future soldier systems are being developed that can display a soldier's geo−location on a portable, wearable digital display but common NATO symbology does not exist for displaying these soldiers on a map. NATO Land Capability Group 1 (LCG 1) has identified a need to develop and validate common symbology for the individual soldier that can be displayed on a wide range of digital display types, to improve the joint interoperability of NATO C4I information systems at the dismounted soldier level.
National symbology sets were provided by LCG1 for a heuristic analysis based on symbology standards and guidelines in the military domain, and in the areas of human factors and symbol adaptability to digital displays. The review of existing symbol sets, provided by LCG1 indicated that they generally fell short of the ideal. A new symbol concept was developed to better conform to the heuristic framework and a future plan of laboratory and field testing was proposed.
Suggestions for improving the design and development of soldier system symbology are provided and opportunities afforded by hardware and software capabilities are discussed.

(U) On met au point des systèmes de combattant du futur qui peuvent indiquer la position géographique d'un soldat sur un écran numérique portable, sauf qu'une symbologie commune de l'OTAN n'existe pas pour l'affichage de ces soldats sur une carte. Le 1er Groupe de l'OTAN sur les capacités terrestres (LCG 1) a cerné la nécessité de mettre au point et de valider une symbologie commune pour chaque soldat qui peut être affichée sur une grande gamme d'écrans numériques, afin d'améliorer l'interopérabilité interarmées des systèmes d'information C3IR de l'OTAN au niveau du soldat débarqué.
Des ensembles de symbologie nationale ont été fournis par le LCG 1 pour une analyse heuristique fondée sur des normes et des directives de symbologie dans le domaine militaire, ainsi que de l'ergonomie et de l'adaptabilité des symboles aux écrans numériques. L'examen des ensembles de symboles existants, fournis par le LCG 1, indique qu'ils ne sont pas à la hauteur des attentes. Un nouveau concept de symboles a été élaboré afin de mieux respecter le cadre heuristique, et on a proposé un plan futur d'essai en laboratoire et sur le terrain.
Des propositions pour améliorer la conception et le développement de la symbologie du système de soldat sont fournis, et on discute des possibilités offertes par les capacités matériel et logiciel.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Symbology, soldier systems, NATO symbology