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Style Guide for Micro Aerial Vehicle Operator Machine Interface Design

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Defence R&D Canada
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Abstract

Little research has been conducted to study desirable handheld interface design approaches for the control of Micro Aerial Vehicles (MAVs). To address this issue, Defence Research and Development Canada (DRDC) - Toronto performed a focus group study, literature reviews, a spiral development of three Operator Machine Interface (OMI) prototypes, and an empirical experiment that tested various display modes and command control input methods for MAV control. The results of these OMI design research efforts are summarized in this style guide, which provides a generic framework for handheld OMI development. Detailed design solutions will be developed using, in part, the criteria provided in this document. The MAV style guide: 1) Identifies assumptions regarding MAV use that may affect design decisions; 2) Defines the essential components of a handheld MAV OMI; 3) Outlines style guidelines common to OMI control elements; 4) Outlines style guidelines common to OMI displays; and 5) Identifies ideal interaction response times for OMI functions. It is assumed that the major components of an OMI will include manual controls and a touch screen with a diagonal dimension of approximately nine inches. However, as new technologies and displays are developed these guidelines may change due to the evolving design and functionality requirements of MAV systems.

Résumé

Peu de recherches ont été menées sur les approches de conception d'interface portative pour le contrôle des microvéhicules aériens (MAV). Pour explorer cette question, Recherche et développement pour la Défense Canada (RDDC) – Toronto a réalisé une étude auprès de groupes cibles, a analysé la documentation disponible, a procédé au développement en spirale de trois prototypes d'interface opérateur-machine (IOM), et a mené une expérimentation empirique qui a testé plusieurs modes d'affichage et de sollicitations des commandes pour le contrôle des MAV. Les résultats de ces efforts de recherche sur la conception des IOM sont résumés dans le présent guide de style qui fournit un cadre générique pour la mise au point des IOM portatives. Les solutions de conception détaillées seront élaborées en se fondant en partie sur les critères fournis dans ce document. Le guide de style MAV : 1) cerne les hypothèses concernant l'utilisation des MAV susceptibles d'orienter les décisions en matière de conception; 2) définit les composants essentiels d'une IOM portative pour MAV; 3) décrit sommairement les lignes directrices de style communes aux éléments de contrôle d'une IOM; 4) décrit sommairement les lignes directrices de style communes aux affichages d'IOM; et 5) définit des temps de réponse aux interventions de l'utilisateur idéaux pour les fonctions de l'IOM. On présume que les principaux composants d'une IOM comprendront les commandes manuelles et un écran tactile ayant une diagonale d'environ neuf pouces. Toutefois, à mesure que de nouvelles technologies et de nouveaux écrans d'affichage feront leur apparition, ces lignes directrices pourraient changer afin de tenir compte de l'évolution des exigences visant les fonctions et la conception des systèmes MAV.

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Executive summary

Style Guide for Micro Aerial Vehicle Operator Machine Interface Design

Ming Hou; Paul Hillier; Chris Ste-Croix; Harry A. Angel; DRDC Toronto TM 2012-025; Defence R&D Canada – Toronto; March 2012.

Introduction: An important component of a Micro Aerial Vehicle (MAV) system is the Operator-Machine Interface (OMI) of a Ground Control Station (GCS). Soldiers will require a GCS to interact with the flying device they are operating. To control an MAV through a GCS, the soldier requires an embedded OMI that is subject to stringent Human Factors (HF) engineering criteria, such as the amount of sensory data displayed, screen size, resolution, and optimized map and video sensor views. Additionally, the OMI must be easy to learn and be intuitive in function and display. However, little HF research has been conducted to study desirable handheld interface design approaches for MAV control. To address the issue, DRDC Toronto initiated a research effort to provide general OMI design guidelines and requirements in the form of a style guide.

Method: The style guidelines in this report were derived from literature reviews, a focus group study that provided feedback on a prototype OMI, an empirical study that tested various display modes and command control input methods, and a spiral development process applied to three OMI prototypes based on platforms such as the SONY PlayStation Portable, Nokia Internet Tablet, and the Viliv S5 Ultra Mobile Personal Computer. This report guides OMI design and development by: 1) Identifying assumptions regarding MAV use that may affect design decisions (e.g., operator, environmental, and clothing); 2) Defining the touch screen and manual controls of a handheld MAV OMI; 3) Outlining style guidelines common to OMI control elements (e.g., text appearance, colour, alarms, and data entry); 4) Outlining style guidelines common to OMI displays (e.g., sight image, luminance, contrast, symbol and icon characteristics, display layout, and navigation methods); and 5) Identifying ideal interaction response times for OMI functions (e.g., key response, menu selection, etc.).

Significance: This style guide specifies general guidelines for an OMI in order to improve human performance and reduce training requirements. It represents "what" the interface should do in terms of appearance and behaviour, and can be applied to more detailed specifications that define "how" style guidelines are implemented in the application code. These general guidelines will provide a framework for further development of MAV OMIs.

Future plans: A complete OMI system will be developed using, in part, the criteria provided in this report. However, the final GCS of the MAV will dictate the extent to which these style guidelines will be followed. As well, this style guide needs to be reviewed by SMEs to confirm the operator, environmental, and clothing assumptions that are presented. It is expected that the MAV OMI will include manual controls and a touch screen with a diagonal dimension of approximately nine inches. Still, it is not possible to predict all of the new and effective OMI design options that may be developed going forward. Therefore, we expect the specification for the MAV OMI to evolve based on new technologies and displays, which should be reviewed and tested for usability based on criteria such as screen size, mobility, and computing power.

Sommaire

Style Guide for Micro Aerial Vehicle Operator Machine Interface Design

Ming Hou; Paul Hillier; Chris Ste-Croix; Harry A. Angel ; DRDC Toronto TM 2012-025 ; R & D pour la défense Canada – Toronto; mars 2012.

Introduction : Les Forces canadiennes (FC) étudient actuellement le rôle des engins télépilotés (UAV) à tous les niveaux d'opérations. Un système de microvéhicule aérien (MAV) peut être utilisé comme un petit type d'UAV au niveau d'une unité – groupement tactique. Un composant important d'un système MAV est l'interface opérateur-machine (IOM) d'un poste de contrôle au sol (PCS). Le militaire aura besoin d'un PCS pour interagir avec le dispositif volant qu'il exploite. Pour contrôler un MAV à l'aide d'un PCS, le militaire a besoin d'une IOM intégrée assujettie à des critères de conception ergonomique strictes comme la quantité de données sensorielles affichées, les dimensions de l'écran, la résolution de l'affichage, ainsi qu'une cartographique et des vues de capteur vidéo optimisées. De plus, l'IOM doit être conviviale et ses modes de fonctionnement et d'affichage doivent être intuitifs. Toutefois, peu de recherches ont été menées dans le domaine des facteurs humains (FH) sur les approches de conception d'interface portative pour le contrôle des MAV. Pour explorer cette question, RDDC Toronto a lancé un effort de recherche visant à élaborer des lignes directrices et des exigences en matière d'IOM sous la forme d'un guide de style.

Méthode : Les lignes directrices de style présentées dans le rapport découlent d'une analyse de la documentation disponible, d'une étude auprès de groupes cibles qui a fourni de la rétroaction sur un prototype d'IOM, d'une étude empirique qui a testé plusieurs modes d'affichage et de sollicitations des commandes pour le contrôle des MAV, et d'un processus de développement en spirale de trois prototypes d'IOM fondés sur des plateformes telles que la PlayStation Portable de SONY, la Nokia Internet Tablet, et l'ordinateur personnel ultramobile Viliv S5. Le présent rapport oriente la conception des IOM et leur développement de la manière suivante : 1) en déterminant les hypothèses relatives à l'utilisation des MAV susceptibles d'influencer les décisions de conception (p. ex. l'opérateur, l'environnement et l'habillement); 2) en définissant l'écran tactile et les commandes manuelles d'une IOM portative de MAV; 3) en décrivant sommairement les lignes directrices de style communes aux éléments des commande des IOM (p. ex. l'aspect du texte, les couleurs, les alarmes, et l'inscription des données); 4) en décrivant sommairement les lignes directrices de style communes aux affichages d'IOM (p. ex. l'image de vision, la luminance, le contraste, les caractéristiques des symboles et des icones, la mise en forme d'affichage, et les méthodes de navigation); et 5) en déterminant les temps de réponse aux interventions de l'opérateur idéaux pour les fonctions de l'IOM (p. ex. le temps de réaction des touches, le choix des menus, etc.).

Importance : Le Directeur – Besoins en ressources terrestres (DBRT) des FC a lancé le projet « Force terrestre – Renseignement, surveillance, acquisition d'objectifs et reconnaissance (ISTAR) » dans le but d'améliorer la connaissance de la situation des commandants par l'utilisation de capteurs de renseignement, surveillance et reconnaissance (p. ex. les MAV). Le présent guide de style stipule les lignes directrices générales d'une IOM visant à améliorer la performance humaine et à diminuer les besoins en formation. Le guide présente ce que l'interface

devrait être et ce qu'elle devrait faire en ce qui concerne l'apparence et le comportement, et les lignes directrices peuvent s'appliquer à des spécifications plus précises qui définiront de quelle façon elles seront mises en œuvre dans le code d'application. Les lignes directrices générales fourniront un cadre pour le développement ultérieur des IOM pour MAV et contribueront au projet du DBRT en permettant de concevoir des PCS de MAV plus efficaces.

Recherches futures : Un système IOM complet sera élaboré en se basant notamment sur les critères fournis dans le présent rapport. Toutefois, le PCS de MAV final déterminera dans quelle mesure les présentes lignes directrices de style seront suivies. En outre, le guide de style devra être analysé par les experts afin de confirmer les hypothèses relatives à l'opérateur, à l' environnement et à l'habillement qui y sont présentées. On s'attend à ce que l'IOM de MAV comprenne des commandes manuelles et un écran tactile ayant une diagonale d'environ neuf pouces. Cependant, il est impossible de prévoir toutes les nouvelles options de conception d'IOM plus efficaces qui pourront être disponibles dans l'avenir. Par conséquent, on s'attend à ce que les spécifications relatives aux IOM pour MAV évoluent en fonction des nouvelles technologies et des nouveaux écrans qui feront l'objet d'analyses et d'essais pour en vérifier la convivialité en fonction de critères comme les dimensions de l'écran, la mobilité et la puissance de calcul.

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1 Introduction

1.1 The DRDC MAV OMI project

Uninhabited Aerial Vehicles (UAVs) have been vital to military operations such as Intelligence, Surveillance, and Reconnaissance (ISR), and time critical strikes. A sub-set of the UAV family is the Micro-Aerial Vehicle (MAV). MAVs are small, light-weight, and agile UAVs that are typically carried in a backpack and launched either by hand or with a bungee cord. Some MAVs are fixed wing vehicles, while others have hovering capabilities (e.g., Honeywell's RQ-16A T-Hawk MAV). MAVs can reconnoiter "over-the-hill" or "around-the-next house", providing infantry soldiers with much needed Situation Awareness (SA). Ideally, future MAVs will operate autonomously and provide intelligence and reconnaissance capabilities to land forces in densely populated and structurally complicated urban centers (US Army, 2010).

An important component of MAV systems is the Operator-Machine Interface (OMI) of a Ground Control Station (GCS). To control an MAV through a GCS, the soldier requires an embedded OMI that is subject to stringent Human Factors (HF) engineering criteria such as the amount of sensory data displayed, screen size, resolution, and optimized map and video sensor views. Additionally, the OMI must be easy to learn and be intuitive in function and display. However, little HF research has been conducted to study desirable handheld interface design approaches for MAV control.

To address this issue, DRDC Toronto conducted a survey and a focus group study on different types of handheld input devices as potential candidate GCSs (Angel & Ste-Croix, 2008). The focus of this effort was on "what" components are required for a MAV system. Although certain numbers of functional requirements for an OMI were identified through the study, the assessment was based on available handheld technologies in 2008. As well, the recommendations developed in the study were subjective and did not consider empirical investigations or other objective experimental evidence. Additionally, the focus group study did not recommend specific OMI design approaches and left many unanswered questions. In other words, the study did not emphasize "how" to design certain components of the MAV system.

Given the limited screen size of a handheld device, which OMI display mode can give an operator better SA? Given the limited command input options of a handheld device, which MAV command control input method is more effective? Such questions are directly related to "how" to design an OMI that will maintain an operator's SA and thus effectively control the MAV. An empirical study was performed by DRDC Toronto that answered these types of questions and thus provided generic design guidance for a prototype OMI (Hou, et al., 2010). Firstly, more literature on input device design (e.g., Bos & Tack, 2005a and 2005b; Goldberg & Goodisman, 1991; Silfverberg et al., 2001; etc.) and the effects of display size and type (e.g., Minkov & Oron-Gilad, 2009; Minkovet et al., 2007; Redden et al., 2008; etc.) was reviewed. Secondly, the OMI design benefited from established design principles for PC-based UAV interfaces (Hou & Kobierski, 2006; Hou, Kobierski, & Brown, 2007; Hou, Kobierski, & Herdman, 2006) and lessons learned from accidents experienced with highly-automated UAV systems (Parasuraman & Miller, 2006; Miller & Parasuraman, 2007).

Based on these reviews, a spiral development process was applied to three OMI prototypes based on platforms such as the SONY PlayStation Portable, Nokia Internet Tablet, and the Viliv S5 Ultra Mobile Personal Computer (Haylock, 2008; Hou et al., 2009; Hou, et al., 2010). The results of this empirical study provided evidence to support the design guidelines of certain OMI components including display mode and layout of sensor and map views, and command input methods. The findings of the study and further research were then generalized into an OMI style guide that validated and enhanced MAV functional requirements developed in the previous focus group study.

1.2 Overview of the style guide

The goal of this report is to guide the design and development of a handheld MAV OMI by providing a generic style guide for OMI design. In order to achieve this goal, the objectives of this report are as follows:

- Identify assumptions regarding the use of MAVs that may affect design decisions;
- Define the essential components of an MAV OMI;
- Outline style guidelines that are common to all control elements associated with an OMI;
- Outline style guidelines that are common to the display of an OMI; and
- Identify interaction performance requirements that an OMI must achieve.

This style guide needs to be reviewed by Subject Matter Experts (SMEs) to confirm the operator, environmental, and clothing assumptions that are presented. The assumptions that were provided will change depending on the Concept of Operations (CONOPS) and the various systems that will eventually make up the MAV. As well, the overall GCS platform of the MAV will dictate whether or not the general and display guidelines presented can be followed. Nonetheless, these guidelines should be followed as closely as possible.

This style guide specifies general guidelines for the look and behaviour of user interaction with a software application (i.e., the prototype MAV OMI), in order to improve human performance and reduce training requirements. The style guide represents “what” the interface should do in terms of appearance and behaviour, and can also be used to derive more detailed specifications that define “how” style guidelines are implemented in the OMI application code (Avery et al., 1999).

Detailed design solutions will be developed and evaluated using, in part, the evaluation criteria provided in this document. However, this style guide is not intended to be an OMI specification, as the specification for the MAV OMI depends on an evolving design and the required functionality of the system. New designs and technologies develop at a rapid pace, and it is not possible to predict all of the new and effective design options that may be developed. Therefore, as new technologies and displays are developed, they should be reviewed and tested for usability based on criteria such as screen size, mobility, and computing power.

This style guide is derived from a preliminary review of MAV system requirements (Angel & Ste-Croix, 2008), additional literature review and insight gained from OMI designs (Haylock, 2008; Hou et al., 2009), and a DRDC Toronto empirical study (Hou et al., 2010).

2 Assumptions

In order to specify interface element criteria, a number of assumptions were made regarding the likely usage of MAVs. This section outlines a series of important assumptions that affect decisions about the design of OMI elements.

2.1 Operator assumptions

The MAV will likely be deployed within a section. Consequently, it is assumed that a member within the section would have received sufficient training with MAVs and the OMI prior to the mission. It is also assumed that the operator (if left-handed) is able to adapt to the preferred right-handed design of the interface. As well, it is assumed that the operator has corrected 20/20 vision.

2.2 Environmental assumptions

It is assumed that the MAV will operate in a range of lighting conditions. In terms of weather conditions, the range of operational conditions of the MAV is not yet determined, but it is assumed that it will not be able to operate in all conditions, and will be deployed at the discretion of the appropriate personnel.

2.3 Clothing assumptions

It is assumed that the MAV operator will have to operate the OMI while wearing a variety of different clothing items, including:

- The full range of Nuclear, Biological, and Chemical (NBC) clothing including gloves and masks. Compared with less-protective attire, operating the OMI while wearing NBC clothing may result in degradation of operator performance, the level of which will have to be determined through testing and approval by the Department of National Defence (DND);
- Arctic clothing, but not Arctic mitts. Compared with less-protective attire, Arctic clothing may result in a degradation of operator performance, the level of which will have to be determined through testing and approval by the DND;
- Temperate clothing and leather gloves; and
- Summer clothing.

3 OMI components

It is assumed that the major components of an OMI will include a touch screen and manual controls. These components will house the controls and displays of the MAV system. It is not yet known whether the touch screen and manual controls will be separate or integrated into a single system. However, an experiment conducted by DRDC Toronto using a Viliv S5 UMPC (Figure 1) indicated that it would be advantageous to use a handheld device with both touch screen and tactile buttons integrated into a single system (Hou et al., 2010).

Figure 1: Viliv S5 UMPC with 4.8 inch screen

3.1 Touch screen

Previous studies have shown that a 7 inch screen produced negligible differences from a full-sized laptop performance (Minkov & Oron-Gilad, 2009; Minkov et al., 2007; Oron-Gilad et al., 2011; Redden et al., 2008; Redden et al., 2010), and DRDC Toronto also experimented using a device with a modest 4.8 inch screen (Figure 1) with positive results (Hou et al., 2010). However, it is assumed that the ideal touch screen will have a diagonal dimension of approximately nine inches.

Within a touch screen system, the initial touch selects the control (i.e., positions the cursor), and the lift-off activates the function, unless safety or critical mission requirements are associated with the control. If the operator's finger slides off the control, it should be ensured that no selection takes place before the finger is removed from the screen's surface. However, the cursor should either remain on the last control touched or, if safety or critical mission considerations are associated with the control, return to a default position.

The operator should receive visual feedback when a control object has been touched. The feedback should be visually different for selection and subsequent activation of the function, such as when the finger is removed.

Touch screen input buttons should be organized so that critical information is not covered when the operator reaches across the display to activate a control.

Buttons should be activated with low force, and use technologies such as resistance and piezoelectric sensors to reduce fatigue. Resistance for these types of touch screens should be similar to that of alphanumeric keyboards. Table 1 illustrates the recommended resistance for touch screen control activation (Avery et al., 1999):

Table 1: Recommended resistance for touch screen control activation

	Numeric	**Alphanumeric**	**Dual Function**
Minimum	3.5 oz	0.9 oz	0.9 oz
Maximum	14 oz	5.3 oz	5.3 oz

Touch screen control objects should be a minimum of 0.79 square inches. For systems where the operator will be operating the touch screen in vibrating environments, or will be wearing gloves (e.g., NBC, cold weather, fire retardant), the control objects should be 1 square inch. Even though the objects are of a certain size, the actual touch zone should be bigger to compensate for individuals who do not directly touch the object. With this being said, all touch screen control objects should be separated from each other and from the edge of the display by at least 0.125 inches, and there should be no overlapping of touch zones.

3.2 Manual controls

Manual control gives the operator an alternative means of MAV control. The vast majority of focus group participants felt that today's soldiers are familiar with the use of manual controls and would prefer having it as an option. Participants felt that manual controls would be helpful in the following areas:

- Controlling launch;
- Controlling climb;
- As an alternative to controlling flight;
- Performing manual building search; and
- During landing.

Manual controls should give the operator a positive indication of activation, such as tactile, aural, and/or visual feedback of the operation. Function keys should be designed so that vibration due to movement does not cause inadvertent and repeated activation. Fixed function keys can be very beneficial for time-critical, error-critical, or frequently used inputs, and provide the operator the continuous availability of the functions.

There should be an option to adjust the gain of manual controls, depending on when the controls are used. For example, it would be beneficial to have a high gain system when controlling the MAV across long distances. Conversely, a lower gain should be selected if the MAV is being used inside a building.

Manual controls should be set to favour dual-hand control. However, due to spatial restrictions this may not be possible. Since the majority of the CF population are right hand dominant, single-hand controllers should be designed and mounted for use by the right hand.

The effectiveness of input devices is influenced by a number of factors (Wickens et al., 1998) Figure 2 rates potential input devices from best to worst depending on their speed, accuracy, and user preference. Table 2 classifies potential input devices in terms of user workload:

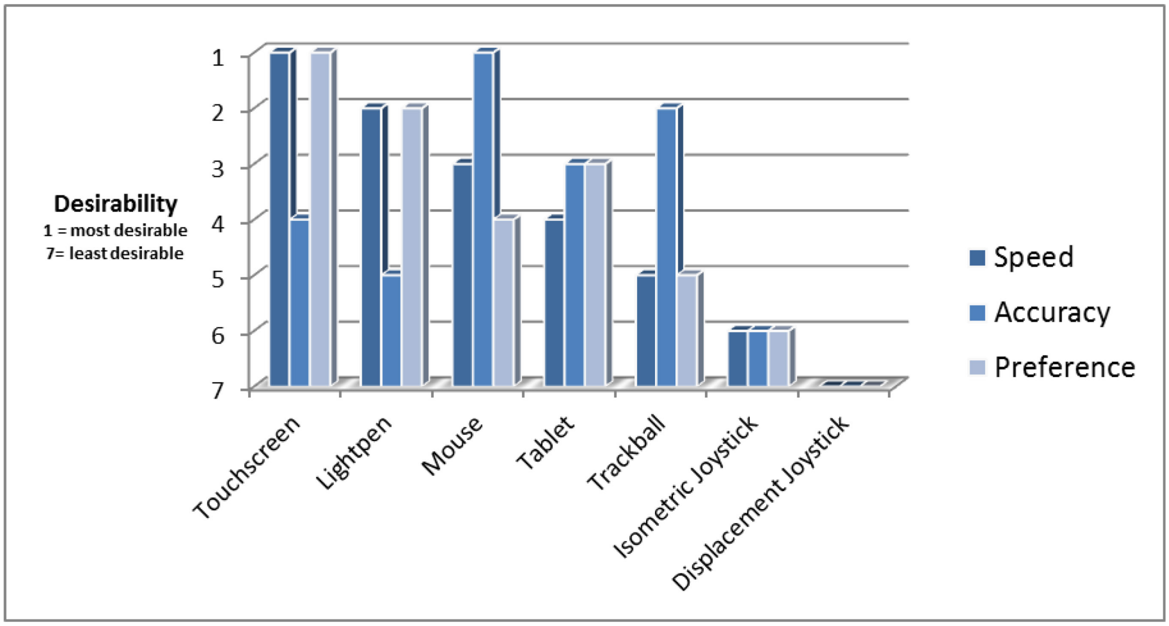

Figure 2: Potential input devices classified in terms of performance (Wickens et al., 1998)

Table 2: Potential input devices classified in terms of workload (Wickens et al., 1998)

Device	Cognitive Load	Perceptual Load	Motor Load	Fatigue
Light Pen	Low	Low	Medium	Medium
Touch Panel	Low	Low	Low	Low
Tablet (Stylus)	High	Medium	Medium	High
Alpha Keyboard	High	High	High	High
Mouse	Low	Medium	Medium	Medium
Trackball	Low	Medium	Medium	Medium

4 General guidelines

This section outlines style guidelines that are common to all control and display elements associated with the OMI of a handheld device. This is by no means an all-encompassing and complete list. However, these general guidelines provide a framework for further development of the OMI.

4.1 Text appearance

Text size depends on the visual distance between the operator and the screen. In simple terms, the further away the screen is, the larger the text size should be. In general, alphanumeric characters should subtend a minimum 15 minutes of visual arc and a maximum of 45 minutes of visual arc, and complex shapes such as symbology should subtend a minimum of 20 minutes of visual arc.

As illustrated in Figure 3, the visual angle is calculated by the following equation, where L refers to the size of the object and D is the distance from the eye (Avery et al., 1999):

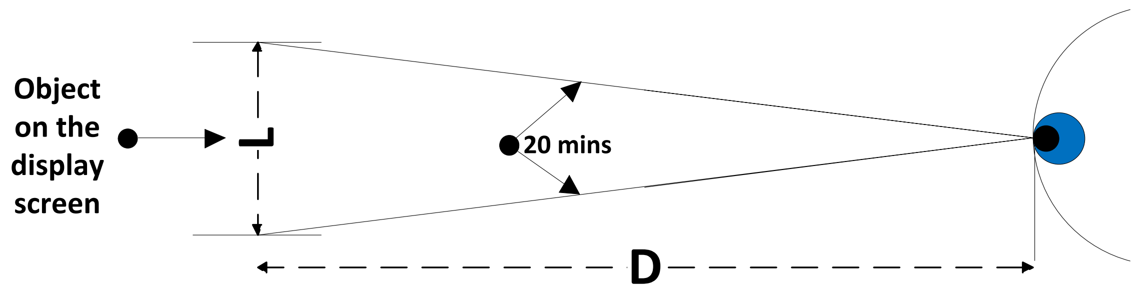

Figure 3: Calculating visual angle

$$\text{Visual Angle (min)} = \frac{(57.3) * (60) L}{D}$$

With respect to legibility, the text should accommodate a 2:3 to 1:1 height-to-width ratio so that each character is easily identifiable.

All alphabetic data should be left-justified, and all numeric data should be right-justified. Decimal point numeric data should be justified with a decimal point instead of a comma.

4.2 Colour

Colour coding on OMI objects should be minimized, as it is difficult to discriminate colours under some operational low light conditions. All colour codes for alerts and warnings should adhere to already existing HF standards and population stereotypes, such as:

- Red—critical system non-operational/failure, warnings;
- Yellow—degraded operation, warnings, priority information, cautions;
- Green—good/fully operational, informational, routine;
- White—inactive, no data; and
- Blue/Cyan—advisory.

Use colour coding with a redundant coding mechanism to accommodate colour blindness, such as shape. Colour should be the secondary code, not the primary code.

4.3 Alarms

Alerting displays should clearly indicate the urgency of the message and whether that message requires a response from the operator. The method used to alert the operator should be contingent upon the urgency of the alert and the need to disrupt the ongoing operator task. These methods should not conflict with already existing signals in the system environment and should not compromise survivability requirements.

To reduce foveal information load, all alerts for non-critical information should be presented in the operator's peripheral field of vision, while ensuring that they are still within the primary visual field.

4.4 Data entry

To reduce operator workload and increase the execution speed of frequently used and critical actions, selection lists, default values, or other methods to minimize alphanumeric data entry should be employed.

The operator should have the capability to control, interrupt, or terminate processes, as well as the ability to reverse or undo the effects of previous actions.

In direct-manipulation interfaces, a click-and-drag interface takes more time when compared to point-and-click. In instances where response time is critical, a point-and-click method is the preferred method (i.e., scrolling down a window).

To reduce keystrokes, fatigue, and errors, there should be an auto-completion capability for situations where operator has to perform frequent or complex data entry. The operator must have the ability to confirm and edit the auto-completion.

5 Display guidelines

This section outlines style guidelines that are common to handheld OMI displays. This is by no means an all-encompassing and complete list. However, these general guidelines provide a framework for further development of the OMI.

5.1 Sight image guidelines

This provides specifications for images on the OMI such as luminance and contrast. It is assumed the OMI will be operated on a tablet PC with a diagonal screen size of approximately nine inches and a resolution of at least 1280 x 768. Display refresh rates must be >28 Hz, and should be >60 Hz.

5.1.1 Display luminance

The display luminance should allow for all data to be readable in all day and night lighting conditions. Displays that are used in direct light should be readable in combined environments consisting of up to 10,000 foot Candle (fC) diffuse illumination and specular reflection of up to 2000 foot Lamberts (fL) glare source (Avery et al., 1999).

Display lighting should not have an adverse effect on external unaided night vision or, when required, on the operator's capability to obtain required information external to the MAV while employing night-vision goggles.

5.1.2 Display contrast

The contrast of all displayed information should be adequate for visibility in illumination environments ranging from total darkness to high ambient.

The display luminance and contrast should not change more than plus or minus 20% when changing from one type of information display to another (e.g., from a map display to a video display). No random bright flashes should occur during this switching.

The display brightness should be operator-adjustable from 'Off' to maximum brightness, to allow for readability in a full range of ambient lighting conditions.

The brightness of illuminated indicators should be at least 10% greater than the immediate background.

5.2 Symbol or icon characteristics

These guidelines should be followed while displaying symbols or icons on the OMI.

The cursor shape should vary in shape to provide visual feedback to the operator depending on the functionality being assessed or the system mode. For instance, an arrow should be selected when pointing or selecting items, crosshairs should be used when grouping or drawing items, and an hourglass should be used when a selection is activated.

The cursor should always be visible on the display, and it should change shades, colours, or intensity to remain visible if it is superimposed on menu selections, buttons, icons, or other screen features.

Target reticules should be composed of both light and dark pixels to ensure visibility when superimposed on both light and dark backgrounds. The target reticule should include a dot or other visual indicator in the centre to represent the point of impact, and should not obscure the visibility of the target.

In order for the operator to detect changes in MAV attitude, visual cues such as colour shading or patterns should be provided. Pitch lines and numbers should be provided where exact information is required.

5.3 Tactical display guidelines

These guidelines pertain to the layout of the display and methods of navigation.

5.3.1 Display layout

Menus should be designed so that there are no more than 10 options per menu, and preferably no more than three to five.

When the cursor rests upon a specific menu option, that option should be highlighted to provide the operator visual feedback of the selection.

In general, screens with the most important task information should be located in the upper-left corner of the screen, unless another arrangement is more operationally logical. Critical information should be visually set apart from other information.

All controls and screen elements with the same function should have the same appearance.
While overlaying maps or other objects, the operator should be able to modify the contents of the overlay by adding, deleting, editing, or relocating labels and symbols.

Information on the screen should be organized so that compatible information is grouped together (i.e., information proximity compatibility).

In multifunction displays, colour should be used to facilitate focused attention recall of those variables that are uniquely coloured in the display.

Physical space should be used as the predominant factor in the perceived organization of an information display.

When using windows, information and controls required to perform a specific task should be located within the same window.

5.3.2 Navigation methods

When the cursor navigates through specific menus, there should be an indication when a specific menu option will take the operator to a submenu (e.g., arrowhead or ellipse).

To complete a task, the user should be provided with a navigational route through the window/menu hierarchy, whereby the flow of each thread through the hierarchal structure is a logical sequence of end-to-end processes. The system should provide the operator a clear indication of where they are within the hierarchal task or operational sequence, as well as navigational aids that help operators identify where they are in the hierarchal menu structure.

6 OMI Interaction Response Times

The MAV project requires that a number of interaction response times be identified for the following specific OMI devices:

- The *Question and Answer Dialog* should have a response time of approximately 0.5 to 2 seconds.
- *Menu Selection* should have a response time of less than 0.2 seconds.
- The response time for *Form Filling* should be function dependent.
- *Graphic Interaction* (i.e., receiving feedback from a selected object) should have a response time of less than 0.2 seconds.
- *Function Key* should have a response time of less than 0.2 seconds.
- The response time for *Function Key* (from depression to response completed) should be function dependent.
- *Key Response* (from depression until positive response) should have a response time of 0.1 seconds.
- *Key Response* (from depression to change in display indicator) should have a response time of 0.2 seconds.

References

Angel, H.A., & Ste-Croix, C. (2008). *Extreme Agility – Micro Aerial Vehicle Statement of Requirements Development Focus Group* (CR2008-135). Toronto, Canada: Defence Research and Development. Contract No. W7711-067989.

Avery, L., Sanquist, T., O'Mara, P., Shepard, A., & Donohoo, D. U.S. Department of Defense, (1999). *U.S. army weapon systems human-computer interface style guide.* (PNNL--11385). Richland, WA: The Pacific Northwest National Laboratory.

Billings, D. R., & Durlach, P. J. (2008). The effects of input device and latency on ability to effectively pilot a simulated micro-UAV. In *Proceedings of Human Factors and Ergonomics Society Annual Meeting*, 52(27), 2092-2096.

Bos, J.C. & Tack, D.W. (2005a). Review: Input device alternatives for infantry soldiers. DRDC Toronto (CR 2005-026). Defence R&D Canada: Ottawa, ON.

Bos, J.C. & Tack, D.W. (2005b). Input device investigation for future dismounted soldier computer systems. DRDC Toronto (CR 2005-052). Defence R&D Canada Toronto: Toronto, ON.

Goldberg, D. & Goodisman, A. (1991). Stylus user interfaces for manipulating text. In *Proceedings of the Fourth Annual ACM Symposium on User Interface Software and Technology*, pp 127 - 135.

Haylock, T. M. (2008). *A prototype user interface for the control of extremely agile micro-aerial vehicles*. Paper presented at 2008 Unmanned Systems Canada.

Hou, M. & Kobierski, R. D. (2006). Operational analysis and performance modelling for the control of multiple UAVs from an airborne platform. In N. J. Cook, H. Pringle, H. Pedersen, & O. Connor (Eds.), *Advances in Human Performance and Cognitive Engineering Research, Vol. 7. Human Factors of Remotely Operated Vehicles* (pp. 267-284). New York: Elsevier.

Hou, M., Keillor, J., Wong, F., Haylock, T.M., & Somjee, K. (2009). Development of prototype interfaces for the control of a micro-aerial vehicle. In *Proceedings of the International Ergonomics Association 17th World Congress on Ergonomics*. Beijing, China: International Ergonomics Association.

Hou, M., Young, S., Yin, S., & Selvadurai, J.R. (2010). *An Empirical Study on Operator Interface Design for Handheld Devices to Control Micro Aerial Vehicles* (TR 2010-075). Toronto, Canada: Defence Research and Development.

Hou, M., Hillier, P., Angel, H.A., & Ste-Croix, C. (2012). A Preliminary Statement of Requirements for a Micro Aerial Vehicle System (TR 2012-043). Toronto, Canada: Defence Research and Development.

Miller, C., & Parasuraman, R. (2007). Designing for Flexible Interaction between Humans and Automation: Delegation Interfaces for Supervisory Control. *Human Factors, 49*(1), 57-75.

Minkov, Y. & Oron-Gilad, T. (2009). Display type effects in military operational tasks using UAV video images. In *Proc. 53rd Ann. Meeting of the Human Factors and Ergonomics Society*, 71-75.

Minkov, Y., Perry, S. & Oron-Gilad, T. (2007). The effect of display size on performance of operational tasks with UAVs. In *Proc. 51st Ann. Meeting of the Human Factors and Ergonomics Society*, 1091-1095.

Oron-Gilad, T., Redden, E. S. & Minkov, Y. (2011). Robotic Displays for Dismounted Warfighters: A Field Study. *Journal of Cognitive Engineering and Decision Making (5)*1, 29-54.

Parasuraman, R. and Miller, C. (2006). Delegation interfaces for human supervision of multiple unmanned vehicles: Theory, experiments and practical applications. In Salas, E. (Ed.), *Advances in Human Performance and Cognitive Engineering Research: Vol. 7. Human Factors of Remotely Operated Vehicles* (pp. 251-256). San Diego: Elsevier.

Redden, E.S., Pettitt, R.A., Carston, C.B. & Elliott, L.R. (2008). *Scalability of Robotic Displays: Display Size Investigation*. Army Research Laboratory: Human Research & Engineering Directorate, Aberdeen Proving Ground, MD, Tech Rep. ARL-TR-4456.

Redden, E.S., Pettitt, R.A., Carston, C.B. & Elliott, L.R. (2010). *Scaling Robotic Displays: Displays and Techniques for Dismounted Movement with Robots*. Aberdeen Proving Ground, MD, Tech Rep. ARL-TR-5174.

Silfverberg, M., MacKenzie, I.S., & Kauppinen, T. (2001). An Isometric Joystick as a Pointing Device for Handheld Information Terminals, In *Proceedings of Graphics Interface*, Ottawa, ON, 7 – 9 June, 119-126.

Wickens, C., Gordon-Becker, S., & Liu, Y. (1998). *An introduction to human factors engineering*. (1st ed.). Upper Saddle River, NJ: Prentice Hall.

US Army (2010). US Army roadmap for Unmanned Aircraft Systems (UAS) 2010-2035. US Army Center of Excellence, Fort Rucker, AL.

Bibliography

Batkiewicz, T. J., Dohse, K. C., Kalivarapu, V., Dohse, T., Walter, B., Knutzon, J., et al. (2006). *Multimodal UAV Ground Control System.* Paper presented at the 11th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference.

CAE Professional Services (2009). Joint Command Decision Support 21st Century Technology Demonstration: Human Factors Style Guide. DRDC Toronto Contract Report (CR 2009-047), March 2009.

Chittaro, L. (2010). Distinctive aspects of mobile interaction and their implications for the design of multimodal interfaces. *Journal on Multimodal User Interfaces*, 3, 157-165.

Donmez, B., Graham, H., & Cummings, M. L. (2008). *Assessing the impact of haptic peripheral displays for UAV operators* (No. HAL2008-02). Cambridge, MA: MIT.

Draper, M., Calhoun, G., Nelson, J., & Ruff, H. (2006). Evaluation of Synthetic Vision Overlay Concepts for UAV Sensor Operations: Landmark Cues and Picture-in-Picture. (AFRL-HE-WP-TP-2006-0038). Air Force Research Laboratory: Warfighter Interface Division.

Endsley, M.R. (1988). Design and evaluation for situation awareness enhancement. In *Proceedings of the 32nd Annual Meeting of the Human Factors Society*, *32*(2), 97-101.

Endsley, M.R. (2000). Direct measurement of situation awareness: Validity and use of SAGAT. In M.R. Endsley & D.J. Garland (Eds.), *Situation awareness analysis and measurement*. Mahwah, NJ: Lawrence Erlbaum Press.

Faul, F., Erdfelder, E., & Buchner, A. (1996). G*Power: A general power analysis program. *Behavior Research Methods, Instruments, & Computers, 28,* 1-11.

Fong, T. W., Cabrol, N., Thorpe, C., & Baur, C. (2001). A personal user interface for collaborative human-robot exploration. In *Proceedings of the International Symposium on Artificial Intelligence, Robotics, and Automation in Space*. Montréal, Canada.

Fong, T., Thorpe, C., & Glass, B. (2003). PdaDriver: A handheld system for remote driving. In *Proceedings of IEEE International Conference on Advanced Robotics*. Coimbra, Portugal.

Global Security. (n.d.). *Unmanned aerial vehicles (UAVs)*. Retrieved from http://www.globalsecurity.org/intell/systems/uav.htm.

Hart, S. G. & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In Hancock, P. A., & Meshkati, N. (Eds.), *Human Mental Workload* (pp. 139-183). Amsterdam, Holland: North-Holland.

Hou, M., Kobierski, R. D., & Brown, M (2007). Intelligent Adaptive Interfaces for the control of multiple UAVs. *Journal of Cognitive Engineering and Decision Making*, *1*(3), 327-362.

Huttenrauch, H., & Norman, M. (2001). PocketCERO –mobile interfaces for service robots. Paper presented at the *Mobile HCI 2001: Third International Workshop on Human Computer Interaction with Mobile Devices*. Lille, France.

Integrated Soldier System Project. (n.d.). In Wikipedia. Retrieved March 13, 2012, from http://en.wikipedia.org/wiki/Integrated_Soldier_System_Project.

Miller, C., Funk, H., Goldman, R., Wu, P., & Pate, B. (2003) A Playbook Approach to Variable Autonomy Control: Application for Control of Multiple, Heterogeneous Unmanned Air Vehicles. In Pro*ceedings of FORUM 60, the Annual Meeting of the American Helicopter Society*. Baltimore, MD. Retrieved from http://www.sift.net/sites/default/files/documents/2004/MGFWP-AHS04-fin.pdf.

Murphy, A., Wu, P., & Miller, C., (2007). *Literature review of HCI concepts for multiple unmanned vehicle supervisory control*. Minneapolis, MN: Smart Information Flow Technologies.

Perlin, M. (2008). Development of Prototype Interfaces for Controlling an EAMAV (W8485-0-XKCF/A). Toronto, Canada: Defence Research and Development Canada.

Pittman, D. (2010). Collaborative Micro Aerial Vehicle Exploration of Outdoor Environments. Unpublished master's thesis, Massachusetts Institute for Technology (MIT), Cambridge, MA.

Quigley, M., Goodrich, M.A., & Beard, R.W. (2004). Semi-autonomous human-UAV interfaces for fixed-wing mini-UAVs. In *Proceedings of the IEEE International Conference on Intelligent Robots and Systems*, 2457-2462.

Rutley, M. (2005). *Design, rapid prototyping and evaluation of a controller interface for a remote reconnaissance vehicle*. M.Sc. thesis, Loughborough University, Loughborough, UK.

Smyth, B. & Cotter, P. (2002). The plight of the navigator: Solving the navigation problem for wireless portals. In P. De Bra, P. Brusilovsky, and R. Conejo (Eds.), *Lecture Notes in Computer Science*, 2347/2006, 328-337.

Statement of Work: Extreme Agility- Micro Aerial Vehicle Statement of Requirements Development Focus Group (2007, September 11). Toronto, Canada: Defence Research and Development.

Watts-Perotti, J. & Woods, D.D. (1999). How experienced users avoid getting lost in large display networks, *International Journal of Human Computer Interaction*, 11(4), 269-299.

Wheatley, S. (2004, October). *The time is right: Developing a UAV policy for the Canadian forces*. Paper presented at 7th annual graduate student symposium of the Royal Military College. Kingston, Canada.

Yin, S., & Selvadurai, J. (2010). *Experiment Design for Interface Comparison on the Performance of Virtual EA-MAV Operation on Control type and Display Mode* (CR 2008-135). Toronto, Canada: Defence Research and Development Canada.

List of symbols/abbreviations/acronyms/initialisms

CF	Canadian Forces
COTS	Commercial-off-the-shelf
CONOPS	Concept of Operations
DOD	(United States) Department of Defense
DND	Department of National Defence
DRDC	Defence Research & Development Canada
MAV	Micro Aerial Vehicle
GCS	Ground Control System
HF	Human Factors
ISAF	International Security Assistance Force
ISSP	Integrated Soldier System Project
MOTS	Military-off-the-shelf
NBC	Nuclear, Biological, and Chemical
OMI	Operator-Machine Interface
PDA	Personal Digital Assistant
RC	Radio Controlled
SME	Subject Matter Expert
SOR	Statement of Requirements
TUAV	Tactical Unmanned/Uninhabited Aerial Vehicle
UAV	Unmanned/Uninhabited Aerial Vehicle
UMPC	Ultra Mobile Personal Computer
UV	Unmanned/Uninhabited Vehicle

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Little research has been conducted to study desirable handheld interface design approaches for the control of Micro Aerial Vehicles (MAVs). To address this issue, Defence Research and Development Canada (DRDC) - Toronto performed a focus group study, literature reviews, a spiral development of three Operator Machine Interface (OMI) prototypes, and an empirical experiment that tested various display modes and command control input methods for MAV control. The results of these OMI design research efforts are summarized in this style guide, which provides a generic framework for handheld OMI development. Detailed design solutions will be developed using, in part, the criteria provided in this document. The MAV style guide: 1) Identifies assumptions regarding MAV use that may affect design decisions; 2) Defines the essential components of a handheld MAV OMI; 3) Outlines style guidelines common to OMI control elements; 4) Outlines style guidelines common to OMI displays; and 5) Identifies ideal interaction response times for OMI functions. It is assumed that the major components of an OMI will include manual controls and a touch screen with a diagonal dimension of approximately nine inches. However, as new technologies and displays are developed these guidelines may change due to the evolving design and functionality requirements of MAV systems

Peu de recherches ont été menées sur les approches de conception d'interface portative pour le contrôle des microvéhicules aériens (MAV). Pour explorer cette question, Recherche et développement pour la Défense Canada (RDDC) – Toronto a réalisé une étude auprès de groupes cibles, a analysé la documentation disponible, a procédé au développement en spirale de trois prototypes d'interface opérateur-machine (IOM), et a mené une expérimentation empirique qui a testé plusieurs modes d'affichage et de sollicitations des commandes pour le contrôle des MAV. Les résultats de ces efforts de recherche sur la conception des IOM sont résumés dans le présent guide de style qui fournit un cadre générique pour la mise au point des IOM portatives. Les solutions de conception détaillées seront élaborées en se fondant en partie sur les critères fournis dans ce document. Le guide de style MAV : 1) cerne les hypothèses concernant l'utilisation des MAV susceptibles d'orienter les décisions en matière de conception; 2) définit les composants essentiels d'une IOM portative pour MAV; 3) décrit sommairement les lignes directrices de style communes aux éléments de contrôle d'une IOM; 4) décrit sommairement les lignes directrices de style communes aux affichages d'IOM; et 5) définit des temps de réponse aux interventions de l'utilisateur idéaux pour les fonctions de l'IOM. On présume que les principaux composants d'une IOM comprendront les commandes manuelles et un écran tactile ayant une diagonale d'environ neuf pouces. Toutefois, à mesure que de nouvelles technologies et de nouveaux écrans d'affichage feront leur apparition, ces lignes directrices pourraient changer afin de tenir compte de l'évolution des exigences visant les fonctions et la conception des systèmes MAV.

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style guide; style guideline; design guide; display guideline; operator machine interface; micro aerial vehicle; handheld device; UAV

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