Human Factors HMI Requirements

Marianne Moller - AIF

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<td>Addition of BAES comments. Addition of DNA comments. Addition of THAV comments.</td>
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1 Scope of Document

This document intends to gather existing Human Machine Interface/Interaction (HMI) requirements and adapt them to the needs of Advanced-Surface Movement Guidance and Control System (A-SMGCS) HMIs.

Because HMIs in A-SMGCS are the link between the ATM equipment system and the users who are controllers, pilots and drivers of vehicles, the document covers both the onboard and the ground elements of the system and gives general rules to ensure coherency between all operator’s HMIs.

The HMI requirements are intentionally kept as general as possible, especially on the airborne side, because the operational requirements related to higher level of A-SMGCS implementation (particularly levels III and IV) are not well known today, and because the HMI must also be in accordance with the existing cockpit philosophies which may differ from one manufacturer/supplier to the other.

The purpose of the document is thus not to go into implementation details of the HMI on the various system applications, either the ground or the onboard part, but to establish the general requirements of Human Machine Interface (HMI) for the A-SMGCS. It is however mainly aimed at providing a practical approach to establishing HMI harmonisation, at the level of HMI mechanism, look and feel for all the actors involved in the airport traffic management (ATCOs, pilots and drivers) even though the HMI design is heavily dependent on the context.

The HMI design is essential for ensuring a good situational awareness, that is to say the coherence between the image created by the system (what the HMI shows) and the real state of that system.

This document is split into four parts:
- The first one, Section 2, is mainly dedicated to provide general HMI design rules so as to insure coherency between ATCOs, pilots and drivers HMIs.
- The second one, Section 3, is focussed on ground related HMIs requirements taking into account vehicle HMI requirements. A special emphasis is put on vehicle and flight deck HMI harmonisation.
- The third one, Section 4, deals with HMIs requirements specific to aircraft flight deck.
- The fourth one, Section 5 deals with the implications of the Human Factors HMI requirements on the EMMA project.

2 General HMI Guidelines

This section provides a set of guidelines that should be taken into account in order to provide the operator (ATCO, pilots and drivers) with a high level of safety and ease of use whilst minimising training requirements. It is divided in two main parts:
- The first presents high-level principles of a human-centred design process.
- The second gives recommendations for ease of use organised in a double-entry table:
  - One for human oriented criteria,
  - The other for object oriented criteria,
so as to facilitate the access to the relevant information on a particular subject.

Note: requirements included in this section have been compiled from information obtained from a number of sources. These sources include [4, [5, [6], [7], and Airbus France Human Factors department expertise.

2.1 High level principles of a Human-centred design process

The principles described hereafter have to be respected to build an operational system-user interface, and will have to stay in the designer's mind throughout the design process.
The human-centred principles have to be carefully taken into account because all criteria that are linked to the operator’s task will impact fundamental dimensions of the activity such as workload, situation awareness, performance, stress, and tiredness, etc. They also drive the technical requirements of the automation needed to support the activity.

Some questions could arise from this approach:

- When a new function is going to be implemented, the designer has to wonder: is the new function necessary?
- When will it be used during the activity?
- What task does it imply for the operator?
- How will the task be done?
- Is the information about the function easy to perceive on the interface?
- Is the control interface / device appropriate for managing the function?

and many more in relation to the operational use of the system by the operator.

General principles and restrictions to be taken into consideration in order to identify and to specify inherent problems in representation optimisation and system-user information exchanges, can be summarised as follows:

The following general principles and restrictions should be taken into consideration in order to optimise information representation and information exchange between system and user:

- **Dialogue accessibility, rapidity and efficiency**: The operator should be able to access information as quickly as possible.

- **Operators’ information expectation and needs**: The concern is to evaluate the priority of the information and its degree of complexity; to select the relevant information needed to carry out the task. Vague, ambiguous or contradictory data could lead to hesitation or mistakes.

- **System behaviour feedback**: The operators must always be informed, through appropriate symbology or messages, of what is happening.

- **Compatibility** between information provided by the system and natural expectations of users in terms of system feedback. Compatibility of an application is defined by the capacity of the system to provide information, which fits the operator activity (comfort, ease of use and communication).

- **Information Display**: principles of information display are the following:
  - Visual and accessibility comfort,
  - Readability,
  - Intelligibility,
  - Ease of discrimination,
  - Ease of interpretation,
  - Ability to associate or differentiate the information,
  - Relevance of how the information is organised,
  - Consistency of display.

- **Operational utility of information**: Operators should not have to memorise too much data or overly long procedures. They have to be realistic, representative of the situation, and suitable with each interaction component. All the support but only the support that is required by the task should be available on the interface in order not to overload the working position or the operator. Questions to be asked concern information utility, functions and tools utility, task chronology, procedure suitability.
- **Full control of the system**: The operators must be permanently kept in the control loop whilst operating the system. Operators must always keep the full control of the system.

- **Coherence and Homogeneity** of principles used in different parts of the software: This implies a stability of the conception choices. There must be a homogeneous logic from one application to another, both at procedure level and at the level of displayed information. This coherence makes the system behaviour more predictable for the operators, improves their situation awareness and eases the operator’s familiarity with the required procedures.

- **Precision and reliability** of devices and interfaces. The operators must develop confidence in the system they use.

- **Cooperation and information exchanges** between 2 or more operators: This is an important crew resource management (CRM) dimension of the activity. HMIs have to ease this collaboration and have to be adapted to human communications in relation with the task allocation.

- A good **Interface Handling** will be ensured by the following principles:
  - Postural, tactile and accessibility comfort.
  - Appropriate feedback (consistent, timely, significant and local).
  - Action conciseness (the interface enables the operator to perform a task with few actions).
  - Action guidance (the interface guides the operator in her/his actions).
  - Action consistency (respect of the information presentation rules).
2.2 Usability recommendations

2.2.1 Human-oriented criteria

The following table gives the usability criteria that are linked to the operators’ tasks. These criteria will be used to provide the system HMI designer with usability recommendations (see 3.2.3).

<table>
<thead>
<tr>
<th>USABILITY</th>
<th>Efficiency</th>
<th>Flexibility</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Performance: speed/error number in task executing</td>
<td>Dialogue facilities</td>
</tr>
<tr>
<td></td>
<td>Coherence in information display and in commands</td>
<td>Facility in using short cut</td>
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<td></td>
<td>Feedback on actions</td>
<td>Facility in finding a preceding state</td>
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<td></td>
<td>Limitation of information to stock in short term memory</td>
<td>Facility in interrupting a task and in going back to it after a given time</td>
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<tr>
<td></td>
<td>Facility in detecting a warning</td>
<td>Protection of critical commands</td>
</tr>
<tr>
<td></td>
<td>Protection of critical commands</td>
<td>Respect of user vocabulary</td>
</tr>
<tr>
<td></td>
<td>Respect of user vocabulary</td>
<td></td>
</tr>
</tbody>
</table>

2.2.2 Object oriented criteria

The following table gives the criteria relating to display and controls, which are linked to the operators’ tasks, that will be used to provide the system HMI designer with usability recommendations (see 3.2.3).

<table>
<thead>
<tr>
<th>Display</th>
<th>Graphical representation</th>
<th>Controls</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Menu</td>
<td>Hard keys (pushbuttons, rotators…) or dedicated controls (side stick, NWS…)</td>
</tr>
<tr>
<td></td>
<td>Form-filling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pictures (cartography, video…)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soft keys</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scale</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Textual representation</td>
<td></td>
</tr>
<tr>
<td>Human oriented criteria</td>
<td>Recommendation</td>
<td>Object oriented criteria</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Performance</td>
<td>The best compromise should be reached between the rapidity of an action on the HMI and the numbers of data entry errors</td>
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<td>Principles</td>
<td>User perspective. A sequence of transactions should be designed to be logical from the perspective of the user, not from the perspective of computer processing or ease of programming</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Minimal user actions. Interactive control logic should permit completion of a task with the minimum number of actions. However, this should not be to the detriment of situation awareness or consistency</td>
<td>All</td>
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<td>Information display</td>
<td>Simplicity. Information should be presented simply and in a well-organised manner. Ways to achieve simplicity include the following: Clutter-free. The screen should be orderly and clutter-free. Consistency. Information should be presented in consistent, predictable locations Simplicity of language. The language used should be plain and simple Logical grouping. Data items on a screen should be grouped on the basis of some logical principle. Directly usable form. Information shall be presented to a user in directly usable form; a user shall not have to decode or interpret data. Partitioning data among pages. Data should be gathered logically to help the user in his tasks Text legibility: Fonts used for texts should be legible with adequate size and contrast</td>
<td>All</td>
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<tr>
<td></td>
<td>Usable, essential data for an interaction. The data needed for an interaction shall be displayed in a directly usable form</td>
<td>All</td>
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<tr>
<td></td>
<td>Whole data sets. Whenever possible, users should be able to see the whole data set of interest, for example, an entire page, map, or graphic.</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Information density. Information density should be minimised, in particular, for displays used for critical task sequences</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Ordering group of options. Groups of options in a menu shall be ordered according to user’s logic.</td>
<td>Menu Graphical representation</td>
</tr>
</tbody>
</table>
**Efficiency** | **Performance** | **Information display** | **Number of options.** The number of options in a menu should not be more than ten or less than three. | **Menu** | **Graphical representation**
| **Amount of information.** Paging or scrolling can be used when the amount of information to display does not allow display on a single page | **Menu** | **Graphical representation**
| **Page numbering.** If paging is required, the page number and total number of pages shall be displayed, when appropriate | **Graphical representation**
| **Discrimination, luminance:** The contrast between text and background shall allow a good legibility of the text. | **All**

**Guidance**

| **Default entries.** Wherever possible, default entries shall appear in their fields when a form is displayed in form-filling interactions. | **Form-filling** | **Graphical representation**
| **Options at completion of a transaction.** A process should never leave a user without further available options and should provide next steps or alternatives. | **All**
| **Display of all options.** A menu shall display explicitly and completely all options available to a user at the current step in a transaction sequence | **Menu** | **Graphical representation**
| **User guidance.** If the computer is waiting for input from a user, it shall indicate clearly where the input is expected and what type of information is expected | **All**
| **Task guidance.** If a user must perform several actions to complete a task, the application should guide the user with the actions that need to be performed | **All**
| **Singular presentation of questions.** Questions shall be presented one at a time and shall not require the user to answer more than one question at a time. To the extent possible, users shall be provided a default or a list of the most appropriate responses from which they may select the desired response | **All**
| **Location of guidance messages.** Guidance messages shall always appear in a consistent location on the display | **All**
| **Duration of guidance messages.** If a computer requests information from a user, it should remain visible until the user complies or takes some other action | **All**

**Particular points**

| **System interrupts.** A system shall interrupt a user only when necessary to guide the user for a response, to provide essential feedback, or to inform the user of errors. | **All**
| **Menu activation/deactivation.** A menu is activated by a click and requires another click, to be deactivated | **Menu** | **Graphical representation**

**Actions**

| **Consistent control actions.** Interactive control actions concept should be consistent within an application and between applications | **All**
### Efficiency

<table>
<thead>
<tr>
<th>Coherence</th>
<th>Principles</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>The system should be consistent with the displayed information and also with the action to be carried out</strong>: the same action will give the same result, the same information will require the same action and the same action will be executed in the same way</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Sequence compatibility with source document.</strong> If questions require entry of data from a source document, the question sequence shall match the data sequence within the source document</td>
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</tr>
<tr>
<td>Information display</td>
<td><strong>Consistent screen structure.</strong> Screens throughout a system or application shall have a consistent structure that is evident to users</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td><strong>Consistency.</strong> Label locations and formats should be consistent. <strong>Consistent screen elements.</strong> Elements of screens such as headers, fields, and labels shall have the same appearance and relative location throughout a system</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Consistency.</strong> The forms and formats of form-filling interactions shall be consistent and logical throughout an application and related applications.</td>
<td>Form-filling Graphical representation</td>
</tr>
<tr>
<td></td>
<td><strong>Style.</strong> Menus shall have a consistent style, even if used in different applications</td>
<td>Menu Graphical representation</td>
</tr>
<tr>
<td></td>
<td><strong>Consistent wording and ordering.</strong> Menus and options that appear in different displays and contexts shall be consistent in wording and ordering</td>
<td>Menu Graphical representation</td>
</tr>
<tr>
<td></td>
<td><strong>Presentation of options.</strong> The options in a menu should be presented in a single vertical column, aligned and left-justified</td>
<td>Menu Graphical representation</td>
</tr>
</tbody>
</table>
### Efficiency

<table>
<thead>
<tr>
<th>Information display</th>
<th>Coding. All coding means (brightness, colour, attribute, format, special symbols) shall have a single meaning throughout an application and related applications</th>
<th>All</th>
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</thead>
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<tr>
<td></td>
<td>Consistency within applications. Data display shall be consistent in word choice, format, basic style and colour coding throughout an application and related applications</td>
<td>All</td>
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<td></td>
<td>Consistency across applications. If the same function exists in related applications, it shall be assigned to the same key in all applications</td>
<td>Soft keys</td>
</tr>
<tr>
<td></td>
<td>Single function. A function key should be assigned to only one function</td>
<td>Soft and Hard keys</td>
</tr>
<tr>
<td></td>
<td>Consistent wording and structure. The wording and grammatical structure of displayed data and labels shall be consistent throughout an application and related applications</td>
<td>Text</td>
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<tr>
<td></td>
<td>Instructions and error messages. Instructions and error messages shall appear in a consistent location on the screen</td>
<td>Text</td>
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<td></td>
<td>Pop-up menu location. A pop-up menu shall appear in a location that is coordinated with the location of the pointer.</td>
<td>Menu</td>
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<tr>
<td></td>
<td>Selecting an option using a pointing device. A user shall be able to select an option on a pop-up menu by moving the pointer onto the desired option and clicking the appropriate button</td>
<td>Menu</td>
</tr>
</tbody>
</table>

<p>| Particular Points   | Maintaining context. An application should provide a means for ensuring that a user maintains an understanding of the context in which a task is being performed | All |
|                     | Display of context information. Information intended to provide a context for the current user-machine interaction shall be distinctive in location and format, and shall be displayed consistently for all transactions within an application and among related applications. | All |</p>
<table>
<thead>
<tr>
<th><strong>Efficiency</strong></th>
<th>Feedback on action</th>
<th>Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Immediate feedback</strong>. Users should receive an immediate, visually detectable and meaningful response to every action</td>
<td>All</td>
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<tr>
<td><strong>Entry acknowledgement</strong>. Every user action shall result in a response from the system</td>
<td>All</td>
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<tr>
<td><strong>&quot;Working&quot; indication</strong>. If a system or application takes more than TBD seconds (to be adjusted according to the context) to complete an operation initiated by a user action, it shall display a &quot;working&quot; message. Whenever possible, a dynamic indication showing the progress of the task shall be supplied</td>
<td>All</td>
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<tr>
<td><strong>Feedback</strong>. If an action has long term consequences, the user shall be informed of these long term consequences when necessary</td>
<td>All</td>
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<tr>
<td><strong>Closure</strong>. The sequence of user actions and computer responses that accomplishes a task should be designed to give the user a sense of completion or closure at the end. <strong>Completion of processing</strong>. If the response to a user action is lengthy, the system shall give a clear and positive indication when processing is complete</td>
<td>All</td>
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<tr>
<td><strong>User expectations</strong>. The result of any correct control entry should be compatible with a user's expectations</td>
<td>All</td>
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<tr>
<td><strong>Field activation</strong>. There shall be a clear indication when a field has been activated and is available for data entry, independently of the cursor position</td>
<td>Form-filling</td>
<td>Graphical representation</td>
</tr>
<tr>
<td><strong>Data entry completion</strong>. There shall be a clear indication when data entry in a field is completed</td>
<td>Form-filling</td>
<td>Graphical representation</td>
</tr>
<tr>
<td><strong>Distinguishing unavailable options</strong>. If a menu contains options that are temporarily unavailable, the unavailable options shall be displayed but clearly distinguishable from available options, except if the menu is imposed by the context</td>
<td>Menu</td>
<td>Graphical representation</td>
</tr>
<tr>
<td><strong>Feedback</strong>. Feedback shall be provided for function key activation.</td>
<td>Soft and hard keys</td>
<td></td>
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<tr>
<td>Efficiency</td>
<td>Limitation of information to stock in short term memory</td>
<td>Principles</td>
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<td></td>
<td>Minimal memory load. The short-term memory requirements on users should be minimised by such means as making displays and interactive sequences self-evident</td>
<td>All</td>
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<td></td>
<td>Independence. The content of each display should stand on its own; users should not have to refer to a previous screen or remember essential information</td>
<td>All</td>
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<td></td>
<td>User memory load. The number of mnemonics, codes, special or long sequences, and special instructions that users may need to learn shall be minimised.</td>
<td>All</td>
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<td></td>
<td>Selection of commands. Commands should be designed to aid memory</td>
<td>Soft and hard keys</td>
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<td></td>
<td>User-detected errors. A user should be able to stop a control task at any point in a sequence to correct an error (for instance modifying a holding pattern)</td>
<td>All</td>
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<td></td>
<td>Fast error detection. User errors should be detected and reported by the system as soon as possible, so that they are easier to correct.</td>
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<td>Error recovery. Whenever possible, conditions and information relevant for user recovery from an error shall be displayed to the user. Users shall be able to correct the error immediately.</td>
<td>All</td>
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<td>Error detection. If a user attempts to initiate an invalid action, the application should display a message stating why the action is invalid, whenever possible. If the attempted action is part of a series of actions, the user should only have to correct the invalid action</td>
<td>All</td>
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<td></td>
<td>Tone of error messages. In general, error messages should be worded as advice or suggestions</td>
<td>Text</td>
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<td></td>
<td>Wording of error messages. Error messages shall be brief, specific, and task-oriented</td>
<td>Text</td>
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<td></td>
<td>Instructions and error messages. Instructions and error messages shall appear in a consistent location on the display</td>
<td>Text</td>
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<td></td>
<td>Correction proposal When an error is detected, the application should provide appropriate information to allow error recovery</td>
<td>Text</td>
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<tr>
<td>Efficiency</td>
<td>Facility in detecting a warning</td>
<td>Principles</td>
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<tr>
<td>Protection of critical commands</td>
<td>Principles</td>
<td>The best compromise should be established between the protection of critical command (lock) and the interface flexibility</td>
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<tr>
<td><strong>Efficiency</strong></td>
<td><strong>Respect of user vocabulary</strong></td>
<td><strong>Principles</strong></td>
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<tr>
<td>Simplicity of language. The language used should be plain and simple.</td>
<td>Familiar wording. The wording of displayed data and labels shall be chosen to reflect the user's point of view and shall correspond to the user's operational language</td>
<td>Text</td>
</tr>
<tr>
<td>Familiar wording. Words in the command language dialog shall reflect the user's point of view and shall correspond to the user's operational language</td>
<td>Transaction wording. The wording shall be consistent within and between applications, and in accordance with the users' operative language</td>
<td>Text</td>
</tr>
<tr>
<td>Consistent syntax. Command language syntax shall be consistent within an application and across related applications</td>
<td>Consistency. Abbreviations shall be used consistently by all systems</td>
<td>Abbreviations</td>
</tr>
<tr>
<td>Consistent wording of commands. All words and their abbreviations in the command language shall be consistent in meaning and spelling from one system to another</td>
<td>Complexity of command language. The complexity of a command language should be minimised</td>
<td>Abbreviations</td>
</tr>
<tr>
<td>Wording of options. The wording of options shall distinguish each option from every other option in the menu.</td>
<td>Labelling single-function keys. A function key shall have a label that clearly identifies the function and clearly distinguishes that function from others</td>
<td>Menu and soft keys</td>
</tr>
<tr>
<td>Abbreviations. If a system or application uses abbreviations in its user-computer interface, the abbreviations shall be unique, distinct, and unambiguous. Their use shall not confuse users and shall not add to system operation time.</td>
<td>Abbreviations</td>
<td>Text</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Dialogue facilities</td>
<td>Principles</td>
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<td></td>
<td><strong>Compatibility with user abilities.</strong> Interactive control systems should be adapted to individual differences and should accommodate the variety of users (culture, computer literacy, user variability...).</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Simplicity.</strong> Interactive control shall be simple and compatible with the lowest anticipated skill of a trained user. Interactive control shall be logical in terms of user task sequences. For a sequence of given tasks, the user should not be compelled, as far as possible, to use different interaction means for a task sequence even if it is not the quickest way. For example, if the operator begins to do a task with keyboard entries, finishing this task by cursor control device entries is to be avoided.</td>
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<td><strong>Interactive concept.</strong> Applications should base their interactions on an object-action concept, that is, a user first selects an object, and then specifies an action.</td>
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<td><strong>Two-action activation.</strong> If menu selection is accomplished with a pointing device, activation shall consist of two actions: (1) designation, in which a user positions the cursor on the desired option (with that option being highlighted when the pointer is on the menu option), and (2) activation, in which a user makes a separate, explicit control entry (clicking the appropriate mouse button).</td>
</tr>
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<td><strong>Appropriate response time.</strong> The response time of a system to a user action shall be appropriate to this type of action.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Maximum response time.</strong> A maximum response time shall be determined for each type of action.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Initial cursor position for pointing devices.</strong> If a user must select among displayed options using a pointing device, the cursor shall be placed, if appropriate, on the default option when the display appears.</td>
</tr>
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<td></td>
<td></td>
<td><strong>Equivalence of input devices.</strong> The system or application shall provide to users the ability to use any of the input devices available to select a menu option.</td>
</tr>
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<td><strong>&quot;Soft&quot; function keys.</strong> If &quot;soft&quot; and &quot;hard&quot; function keys are used, they should have a similar action.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>&quot;Soft&quot; function key activation.</strong> If a screen includes &quot;soft&quot; function keys, and if the application provides a pointing device, a user should be able to initiate a function both by pressing the corresponding &quot;hard&quot; function key and by selecting the soft key with the pointing device</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Dialogue facilities</td>
<td>Principles</td>
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<tr>
<td><strong>User control of pace.</strong></td>
<td></td>
<td>The user, not the computer, shall control the pace of control entries by explicit actions</td>
</tr>
<tr>
<td><strong>Accessibility and identification:</strong> Hard keys should be accessible and easy to identify (visual accessibility and manual accessibility). They should not be masked by other systems</td>
<td></td>
<td>Hard keys Commands</td>
</tr>
<tr>
<td><strong>Priority rules on shared screens:</strong> The dialog means on a shared screen should be checked. There must be a priority law for the different users’ actions and according to the device used for data entries</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td><strong>Facility in using shortcut</strong></td>
<td>Facility in using shortcut</td>
<td><strong>Frequently-used functions.</strong> If a function will be used frequently, if its use is critical, or if its timely use is critical, it shall be initiated with a single key operation</td>
</tr>
<tr>
<td><strong>Facility in finding preceding state</strong></td>
<td>Facility in finding preceding state</td>
<td><strong>User interruption of transactions.</strong> A system or application shall permit a user to interrupt or terminate the current transaction. Each type of interrupt shall have a separate control option and a distinct name: **Cancel, Undo...**which will be consistent within and between applications</td>
</tr>
<tr>
<td><strong>Facility in interrupting a task and in going back to it after a given time</strong></td>
<td>Facility in interrupting a task and in going back to it after a given time</td>
<td><strong>Cancelling or undoing actions.</strong> User actions should be easy to cancel or undo when appropriate (for example activation of a new flight plan cannot be undone</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Easy return to base-level functions.</strong> If functions assigned to a set of keys change as a result of user selection, it shall be easy for the user to return them to the initial, base-level functions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>User control.</strong> Users should be able to suspend, cancel or terminate their own tasks.</td>
</tr>
</tbody>
</table>
### Possibility of system in a non-nominal use
The user should be able to use the same system in a non-nominal situation (for example, loss of a dialogue means, loss of a screen). The task sequence should still be possible.

### System failure
In case of a system failure during an interaction, the system should keep, as far as possible, the maximum of information in order not to have to start again the same interaction.

### Conformity between command shifting and effect meaning
The move direction of the command should be in accordance with the meaning of the effect in order to respect users logic. For example, clockwise corresponds to an increase of the indicator.

### Conformity between movement speed and effect execution
The executed movement speed should conform to the effect execution.

### Avoidance of inadvertent actions
The shape should prevent commands confusion and should avoid actions done by mistake.

### Anthropometrical user adaptation
The commands should be adapted for each user.

### Environment adaptation
Commands should be adapted to the physical environment (vibration for example).

### Commands states
The state of an active command should be displayed directly on hard key. The state of an inoperative command should be displayed directly on hard key.

### Conformity between command force and function
The command force should be adequate to the function.
3 Ground Systems: HMI guidelines focussed on specific A-SMGCS requirements

3.1 ATCOs HMI

3.1.1 State of the art

Note: this section has been prepared taking into account ENAV expertise, in close cooperation with operational people

3.1.1.1 General requirements

REQ 3.1.1 - #1: The use of advanced graphics features in the SWP (Surface Working Position) should be promoted, as it shall contribute to enhance the controller productivity.

REQ 3.1.1 - #2: The SWP should be basically intended to be manned by one controller per time, so each controller will choose his own setting of SWP; for this purpose, it is characterised by a unique set of input devices, which interacts with the graphics display. Anyway it has to be possible to come back to a default setting with a minimal number of actions (1 or 2).

REQ 3.1.1 - #3: The SWP shall integrate typical ATC traffic presentation obtained by means Approach Surveillance sensors (PSR, SSR...) and those derived from A-SMGCS Surveillance sensors (SMRs, MLAT...).

REQ 3.1.1 - #4: The SWP shall provide an HMI suited for both ground and TWR/APP applications as much as possible. (i.e. data representation, the basic mutuality, etc.).

REQ 3.1.1 - #5: The appropriate ATS geography shall be available on the SWP.

REQ 3.1.1 - #6: The SWP shall allow manual labelling of mobiles and made them recognizable from the automatic labelled mobiles.

REQ 3.1.1 - #7: The SWP shall be able to display visually and soundly Surface Conflicts.

3.1.1.2 Main functions requirements

REQ 3.1.1 - #8: The SWP shall provide the HMI to perform the following functions:
  - Surveillance
  - Monitoring and Alerting
  - Routing
  - Guidance
  - Flight Plan management

REQ 3.1.1 - #9: The Area displayed on SWP shall be able to:
  - Display positional information on all aircraft in the movement area and vehicles within the manoeuvring area with a required accuracy.
  - Provide identification and labelling
  - Be immune from adverse effects of weather and topography

REQ 3.1.1 - #10: The SWP shall be able to warn controllers by visual and sound alerts relating of:
  - Runway incursions;
o Taxiway conflict situations;
o Prohibited area penetration;
o Deviation from planned/cleared routes.

REQ 3.1.1 - #11: The SWP shall be able to interact with controllers for guidance function. From the SWP the controller should be able to provide automated guidance of aircraft and vehicles on the airport surface managing the following ground visual aids:

- Automated control of intersection through stop bars
- Taxiway centre line switchable;
- Addressable direction signs

Moreover the status of all Visual Aids should be displayed to the controller.

3.1.1.3 HMI general requirements

3.1.1.3.1 Data Presentation

REQ 3.1.1 - #12: The following airport situation shall be presented to the operator on the SWP:

- Representation of aircraft in air and on surface, vehicles, objects
- Airport and surrounding airspace maps
- Communication windows with other ATCO positions or with other airport stakeholders.
- Alarms windows
- Lists and tables

REQ 3.1.1 - #13: Colours, different levels of brightness, blinking colours shall be used to the following aims:

- Code the status of the flight
- Display video maps and code the background for windows and text
- Draw attention to emergency and/or critical situations
- Identify outstanding actions
- Improve legibility and perception.

REQ 3.1.1 - #14: The information shall be presented so that critical objects are never obscured by less critical ones.

REQ 3.1.1 - #15: To provide a clear awareness of the traffic situation, the following information shall be displayed:

- Digital track symbols on target position
- Different symbols for aircraft and vehicles. On the aircraft label shall be show the aircraft ICAO category (L, M, H).
- Target information (position, speed, identification, flight plan data) on labels and windows
- Conflict alerts (visual and audible)
- Status of the Airfield Lighting and stop bars

REQ 3.1.1 - #16: The symbol of airborne targets, ground targets and vehicles should be different and the controller shall clearly distinguish between them.

REQ 3.1.1 - #17: The controller shall be able to distinguish on the airport maps the landmarks such as:

- Runway thresholds
- Trees
- Obstacles
• Aerials
• Wind socks
• Smokestacks
• Reservoir
• Inner Markers
• VOR
• Sensitive and critical ILS areas
• CAT1/CAT2/CAT3 holding position, stop bars.
And any natural terrain feature or man-made fixed object, permanent or temporary, which has vertical significance in relation to adjacent and surrounding features and which is considered a potential hazard to the safe passage of aircraft.

### 3.1.1.3.2 Capabilities provided to the controller

**REQ 3.1.1 - #18:** The controller shall be able to select his own presentation of display layout using a set of accurate maps of airport layout and surrounding airspace.

**REQ 3.1.1 - #19:** The controller shall be able to manually label aircraft and vehicles. In case of conflict with automated labelling a warning to the controller shall be provided.

**REQ 3.1.1 - #20:** The controller shall be provided with the capability of executing the following actions:

- Setting-up the screen layout
- Correlate, de-correlate a track with a flight plan
- Insert new flight plan, modify, delete flight plans
- Associate a parking bay (gate) to a flight plan
- Enable or disable meteorological maps visualisation.

**REQ 3.1.1 - #21:** The controller shall be able to modify the local QNH and the runway heading.

**REQ 3.1.1 - #22:** The controller shall be able to set-up the RWY in use for arrival and/or for departure.

### 3.1.1.3.3 Surface Conflict Alert function

**REQ 3.1.1 - #23:** The SWP shall provide Surface Conflict Alert alarms on the basis of messages received from the SCA function.

**REQ 3.1.1 - #24:** Alert messages from SCA should result in:

- Acoustic alarms
- Visual alarms

**REQ 3.1.1 - #25:** The controller shall be allowed to activate/deactivate the acoustics alarms for a given conflict.

**REQ 3.1.1 - #26:** After being deactivated, an acoustic alarm shall be re-activated automatically when the risk class increases (e.g., from predicted to actual) or when another alarm (also of the same type) occurs.

**REQ 3.1.1 - #27:** The visual alarm consists of the following graphical aspects:
• Different background and a foreground label colour for the tracks involved in the detected possible conflict or warning
• Segments connecting two tracks in collision using a defined colour
• A new item in a dedicated alarm list

3.1.1.3.4 Routing function

REQ 3.1.1 - #28: The SWP shall be able to show and to assign the planned route to individual aircraft and vehicles to provide safe, expeditious, efficient and free conflict movement from its current position to its intend position.

REQ 3.1.1 - #29: The controller shall be able to modify the assigned route to individual aircraft and vehicles. In case of re-calculation of the route the SWP should show the new route and its changes.

REQ 3.1.1 - #30: The non-respect of the established taxi-route from a track, shall trigger the skipping to the manual guiding modality of the track.

3.1.1.3.5 Guidance function

REQ 3.1.1 - #31: The SWP shall be able to interact with an automatic guided track to guide the aircraft along the established taxi-route by means of Airfield Lights that turn on in front of them and turn off behind, and also by means of stop bars.

REQ 3.1.1 - #32: SWP shall display an alarm when a non-respect of a stop bar from a track occurs.

REQ 3.1.1 - #33: The SWP shall allow the guiding function by managing of the rights of ways and the activation/de-activation of taxi segments and stop bars.

3.1.2 Future Concepts

This section does not deal with HMI requirements, but intends rather to present some advanced concepts from an HMI and technological standpoint.

Note: the concepts presented in this section have been derived from the work of CENA (DNA research centre) division in charge of the conception of advanced HMI’s for ATCOs. This division is composed of specialists in ergonomics, engineers and ATCOs. Its mission is to specify and prototype future HMI, based on advanced concepts, before implementation by STNA (DNA technical services).

3.1.2.1 Introduction

Most of future HMI concepts are related to newly available technologies. However, there are several prerequisites to the integration of these advanced concepts and technologies in the ATC systems:

• No degradation of safety and efficiency
• Improvement of safety or efficiency
• Acceptance of the user

Thus it is expected that the user can manage higher traffic levels with the same safety level, thanks to improved services and advanced technology.

Here is a list of the possible benefits that can be expected from the integration of these future concepts:

• Improvement of data reliability: automated coordination and sharing of the information between ATCO positions, etc.
• Improvement of cooperative aspects linked to ATCO team rotation or handover: automated transmission of the information between ATCO positions, etc.
• Better understanding of the traffic information: more accurate visualisation, selective display of different traffic information, etc.
• Better understanding of the system processing: graphical animations showing the actions of the systems, etc.
• Increase of the number of available information: filtering and grading of the available information, etc.
• User comfort: better visualisation, “less paper”, etc.

3.1.2.2 Some advanced concepts
This section aims at describing some future HMI concepts, in terms of available technology, applications, functions and expected benefits.

• Direct Tactile Interaction:
Direct tactile interaction is the possibility given to the user to interact with the system in more intuitive and direct ways: by writing and moving objects on the screen, without intermediate (keyboard or mouse).

  o Technology:
    ▪ Touch screens.

  o Functions:
    ▪ Gesture recognition: ability of the system to recognise some simple hand-written symbols (e.g. control clearances usually written on strips).
    ▪ Free writing: user possibility to freely write on a screen. This can be combined with OCR (optical character recognition) (very advanced technology).
    ▪ User possibility to modify any information by tactile actions.
    ▪ Direct control of peripherals from screen.

  o Applications:
    ▪ Radar screen controls (zoom, display of selected information, etc.).
    ▪ Electronic stripping systems.

  o Expected benefits:
    ▪ Data reliability: possibility to input some hand-written information in the systems.
    ▪ User comfort: interaction with the system in a direct, intuitive way.
    ▪ Cooperative aspect: better situation awareness especially in case of controllers' team rotation and handover (direct transmission of electronic strips).

• Graphical animation:
Despite its presence in most computer applications, graphical animation only starts to be used in ATC HMI. The main reason is the extreme caution with which graphical animation must be integrated in an ATC process: it must bring useful information about the traffic or the system, and, in any case, it must not interfere with the ATCO work and concentration.

  o Technology:
    ▪ Graphical libraries.

  o Functions:
    ▪ Graphical animation with underlying logic enables the user to follow and visualise the various system treatment steps following his/her logic
(appearance/disappearance of a flight plan, transmission of flight to another position, etc.).

- Applications:
  - All kinds of computer displays (radar screen, environment screen, electronic stripping, etc.).

- Expected benefits:
  - User comfort.
  - Increase in the number of available information.
  - Better understanding of the traffic.
  - Better understanding of the system processing.

- Voice Recognition:
  Voice recognition is the ability of the system to recognise all or part of the radio communications between ATCO and pilot or between ATCOs. Full voice recognition is a very difficult task, which cannot be performed by existing systems. However, some applications, related to the recognition of some specific key words, may be integrated in ATC systems.

  - Technology:
    - Voice recognition software.

  - Functions:
    - Ability to enter vocal radio information in the system.

  - Applications:
    - All kinds of applications needing a vocal input from the ATCO, for instance:
      - Voice recognition of the aircraft call sign in an ATCO/pilot dialog, possibly combined with automatic appearance of aircraft related information.
      - Voice control of peripherals (zoom, display of specific information, etc.).

  - Expected benefits:
    - Data reliability.
    - Increase in the number of available information.
    - Better understanding of the traffic.

- Head up display:
  Already available in some aircraft, the head-up display is a means to superimpose system information to normal outside view. This concept makes its appearance in future projects for tower control displays, with some limitations: as the ATCO is not fixed, it is hard to make the information contextual, e.g. to give the call sign of the aircraft the ATCO is looking to. However, general (non-contextual) information can be made available.

  - Technology
    - Semi-reflecting glass + projector.

  - Functions
    - General information: display information around the edges of the HUD visual field for use by the ATCO when looking outside, such as weather, AMAN or DMAN information.
    - Basic contextual information: give general information about the area the controller is looking to. This can be performed by installing several head-up displays in the direction of each airport area, e.g. in front of the picture windows. This can be useful in partial LVP conditions.
o Applications
  - All kinds of general information display.

o Expected benefits
  - Better understanding of the traffic.
  - User comfort: Allow the user to keep the head-up position, thus avoiding head-up /head-down movements.

3.2 Vehicle Management HMI

Note: requirements included in this section have been compiled from information obtained from a number of sources. These sources include [1], [12], and AMS internal source: Airport Vehicle Management System requirements specification.

3.2.1 Introduction

To date there are very few examples of Airport Vehicle Tracking Systems in the world and they are mainly focused at satisfying Surveillance requirements from the ATC perspective. However other functions should be implemented within A-SMGCS including Control, Guidance and Route planning functions. Moreover, in order to support optimised “gate to gate” operations, an A-SMGCS should be capable of assisting authorized aircraft and vehicles to manoeuvre safely and efficiently on the movement area. So many other actors are involved in vehicles management within the airport environment and their requirements should also be captured.

All these functions require vehicle on board systems supporting drivers in their specific tasks within the airport environment. Practical considerations suggest a common HMI approach for all users although specific personalisation would be allowed by a modular architecture. Furthermore since controllers, pilots and vehicle drivers should be provided with systems with the same level of performance it follows that the HMI requirements should be harmonised between these users, taking account of cost constraints, which clearly depend on the application (e.g. aircraft vs. vehicle). Since A-SMGCS should provide situation awareness not only to the drivers of ATC vehicles but also to all those drivers that are liable to come into proximity with each other, a holistic approach towards vehicle on board HMI requirements seems entirely justified.

Specific implementations will of course depend on actors and cost constraints that in turn vary according to the vehicles equipped and their role in the airport environment. It is therefore likely that more elaborate implementations will be justified for those vehicles entering the manoeuvring area than vehicles restricted to operate in the Apron area. A modular approach to on-board vehicle equipment would therefore allow all requirements to be satisfied by the same general system, with obvious advantages in term of harmonisation and cost effectiveness.

Flexibility and modularity within a general, wide ranging HMI framework should therefore provide the guiding principle for all implementations of vehicle on board systems.

3.2.2 Actors

An A-SMGCS should be designed so that the responsibilities and functions may be assigned to the following users involved in vehicle management in the airport:

- Airport authorities
- Emergency services
- Security services
- Airline operating companies
Other authorities.

In the full configuration, an advanced Vehicle Management System should satisfy requirements of ATS Providers, Airport Operators (e.g. fleet management) and emergency management services (e.g. Fire Fighting). In other words the aim of the System is to satisfy requirements for management of all types of vehicles: follow me (“flyco”), ATC equipment maintenance, Airport maintenance, Fire Fighting, Bird control, Snow plough, Runway sweeper, Emergency, Police (security), Bus, Tug (push/tow), Grass cutter, Fuel, Baggage, Catering, Aircraft maintenance, etc.

3.2.3 Requested functions

Every actor involved in airport vehicle management has specific requirements in terms of functions.

**ATS Providers** have a primary interest in Surveillance and Control (Conflict Alert) of vehicles on the Manoeuvring area in terms of localization and identification of targets. Future development could include support for Guidance and Planning functions for which availability of an advanced vehicle on board HMI would be required. Moreover the limited number of vehicles authorised to operate within the Manoeuvring area would justify a significant economic effort insuring consistency with airborne systems. So within this area of interest there is greater scope for synergy between vehicle and aircraft on board equipment both in terms of technology and HMI harmonization.

Although “it is not practicable to exercise total control over all traffic on the movement area” (ICAO A-SMGCS Manual) some cases may be envisaged for specific measures aimed at avoiding conflict in the apron area.

However support can be given in specific dangerous situations, which may occur in the apron area, such as conflicts between aircraft and vehicles during push back operations. On board HMI could be implemented to provide drivers with alerts to avoid infringement into “active” stands, during push back phases.

**Airport authorities** are interested in safety, fleet management issues and maintenance services. In terms of safety, airport authorities are interested in supporting vehicles authorised to operate in the Manoeuvring area and providing facilities for emergency services (e.g. Fire Fighting) in terms of navigation support.

Concerning fleet management, availability of an advanced message dispatching service and relevant presentation on board, will speed up coordination of ramp vehicle activities (e.g. bus allocation). An efficient implementation of these concepts should be approached with the development of an integrated human-machine interface for vehicle drivers by using computers and automation. Specific function keys could be used by maintenance vehicles to signal to a Central Control Centre the position of precise airport areas requiring maintenance. The location requiring maintenance would be correlated with the position of the maintenance vehicle.

**Airline Operating Companies (AOCs)** have similar needs to Airport authorities, restricted to the Apron area. For fleet management service AOCs can use the infrastructure provided by Airport authorities or realize their own systems. In this case system harmonization is expected in order to have a common fleet vehicle management system.

**Fire Brigade and Rescue services** can benefit from an advanced on board HMI to implement Guidance and Routing functions. More specifically the HMI could present the position of the vehicle on a moving map of the entire airport area displaying primary and secondary roadways, water supplies, significant buildings, landmarks, collection points, etc. Furthermore the driver could receive the shortest route to reach target points so as to satisfy the required response time.
Security services could profit from the possibility of identifying vehicles and drivers, thus allowing access control to restricted areas. This could be implemented by means of badge readers connected to on board equipment containing driver personal data and authorizations. Restricted area infringements can be detected by the security service control centre and signalled to the intruder (e.g. acoustic alarm).

3.2.4 ATCO Vehicle Management

*Note: the ATCO Vehicle Management HMI has been derived from ATCO surveillance HMI requirements. They are the results of a discussion with specialists of ergonomics and ATC operations working in the CENA division in charge of advanced ATCO HMI conception*

There is no ATCO position specifically dedicated to vehicle control. For safety reasons (management of conflicts between aircraft and vehicles), the controlling ATCO shall centralize information about all moving objects on his/her control area. For this reason, the general requirements for ATCO HMI are still valid for ATCO vehicle HMI. The following requirements are specific to vehicle management integration in ATCO HMI:

**REQ 3.2.4 - #1:** Whatever the HMI implemented on a controller working position, the coherence between the information about vehicles presented on the various controller displays and the real external environment shall be respected.

**REQ 3.2.4 - #2:** Vehicles shall be displayed on the same HMIs as aircraft.

**REQ 3.2.4 - #3:** The ATCO shall have the possibility to deactivate vehicle display in non-critical area (all area except TWY and RWY). In the manoeuvring area (TWY and RWY), vehicle display is mandatory.

**REQ 3.2.4 - #4:** Vehicles shall be clearly distinguishable from aircraft. Different symbols and/or colours shall be used. Representation should be harmonized with avionics display to give common situation awareness.

**REQ 3.2.4 - #5:** Depending on the available systems and data, the HMI shall give the possibility to display all kinds of relevant information related to vehicles: identification, route, mission, vehicle alert, etc.

**REQ 3.2.4 - #6:** The ATCO shall have the possibility to manually edit specific information about vehicles (id, route, mission, etc.).

**REQ 3.2.4 - #7:** If a Surface Conflict Alert is available, alerts shall be displayed if a vehicle is in conflict with an aircraft.

3.2.5 Other airport stakeholder Vehicle Management

*Note: this section has been prepared taking into account ENAV expertise, in close cooperation with operational people*

Surveillance HMI for ground control centres should be based on requirements identified for ATS providers (see paragraph 4.2.1). HMI ground centre functionalities specific to each actor are listed below.

**Airport authorities**

The ground control centre HMI should provide support to:

- Surveillance in manoeuvring area (as ATS Provider);
• Localization/identification in other areas to insure efficient fleet management (e.g. identification of closest available vehicles to the area to be served)
• Automatic presentation of airport surface points requiring maintenance actions; this information may be provided by maintenance vehicles (position, classification of detected problem requiring action)

Airline Management Companies (AOCs)
The ground control centre HMI should provide support to:
• Surveillance in manoeuvring area (as ATS Provider)
• Localization/identification in other areas to insure efficient fleet management (e.g. identification of closest available vehicles to area to be served)

Fire Brigade and Rescue services
The ground control centre HMI should provide support to:
• Localisation/identification of all areas of interest (manoeuvring areas, depots, water reservoirs, collection points) to allow the management of available resources.
• Support to drivers to dispatch the best route (Guidance/Routing) to reach the designated point. This information should originate from the ground control centre (and not the vehicle) since only the control centre has visibility over the overall conditions affecting the alternative routes.
• Automatic presentation of airport areas requiring emergency actions; this information may be provided by emergency vehicles (position, emergency type).

Security services
The ground control centre HMI should provide support to:
• Localization and in particular identification of vehicles.
• Presentation of alarms in case of non identified vehicles or non authorised vehicle intruding into restricted areas; identification of drivers provided by on board equipment (e.g. badge, identification, code input through function keys, etc would represent an additional significant enhancement.

3.3 Vehicles on board HMI

Note: requirements included in this section have been compiled from information obtained from a number of sources. These sources include [1], [12] and AMS internal source: Airport Vehicle Management System requirements specification

HMI requirements will be constrained by cost considerations that will in turn depend on the number of potential vehicles equipped and required functionalities.

More specifically, vehicles intended to operate in the Manoeuvring area can justify a more elaborate on board system due to the safety considerations and limited number of vehicles involved.

Such investment probably would not be justified for the other vehicles.

In order to ensure flexibility to meet all user requirements, while capitalising on economies of scale, a modular architecture is recommended.

For vehicles authorised to operate in the Manoeuvring area (authorised vehicles), the following requirements apply:

REQ 3.3 - #1: The HMI should have visual alerts (lights) or alphabetic display or graphic (map) display, possibly with associated audio alerting (see [8]).
REQ 3.3 - #2: The alphabetic or graphic display should have adjustable brightness and contrast controls in order to adapt to all light conditions.

REQ 3.3 - #3: The information displayed on the map should include all objects of interest for the application. Consideration should be given to ensure the map is not too complicated.

REQ 3.3 - #4: The graphic display size should be provided as a sensible trade-off between vision clarity and problems relating to obstruction of drivers view.

REQ 3.3 - #5: Installation should not obstruct the driver’s view or hamper any other vehicle system HMI.

REQ 3.3 - #6: Functional keys should be used for zooming and panning functions. Pre-defined messages should be selected using functional keys.

REQ 3.3 - #7: Acoustic signalling capability and vocal synthesis capability. These forms of alerting are specially recommended in view of the large quantity of visual interference in the airport environment. Radiotelephony remains available as a communication media. New procedures should be defined establishing procedural rules for mixed use of radio communication and new HMI functions.
4 Aircraft Flight Deck: HMI guidelines focused on A-SMGCS requirements

4.1 Introduction

The Airborne part of the overall A-SMGCS air-ground concept aims at providing the flight crew with improved situational awareness and decision aiding on the airport surface. The objectives are:

- Firstly to alleviate the pilot workload in the day-to-day task of navigating around complex airfields,
- Secondly, to prevent potential dangerous errors in aerodrome surface navigation such as for instance runway incursion or take-off from the wrong runway/taxiway,
- Thirdly, improved planning functions in higher A-SMGCS levels are expected to drastically reduce taxi delays in and outbound, thus increasing the overall efficiency of airports.

As an onboard function for navigation on airport is a recent field of investigation, its development will be progressive.

The first step, corresponding to level II A-SMGCS implementation, is limited to providing the flight crews with the guidance function so as to give them a permanent knowledge of the A/C localisation on the airport surface. This function may thus contribute to reduce navigation errors, which mainly occur in low visibility conditions and at unfamiliar airports. This function is defined as optional in this level II A-SMGCS implementation.

This objective is achieved by displaying an electronic moving airport map positioned and oriented relatively to the A/C symbol representing the aircraft position, similarly to what is displayed on a Navigation Display.

A specific database is necessary for this new purpose and based on RTCA / EUROCAE ED99 standard.

In addition, the function provides a set of information useful for obtaining good situation awareness quickly. This information comprises for example (for the basic ones) the name of displayed airport; taxiways, runways and gates will be labelled; important buildings and current ground speed are presented.

The further implementation steps, corresponding to level III and IV implementation level, will complement the function with globally:

- The improvement of the on board guidance function,
- The sharing of traffic situation awareness amongst flight crews and vehicle drivers,
- The introduction of impending infringements and conflict resolution information,
- The introduction of an automated routing service, which will be issued to flight crews and drivers vehicle through ATC clearances.
- Route request initiated by flight crews to ATCOs.
4.2 General HMI requirements/principles applicable to aircraft flight deck

Requirements included in this section are the result of the compilation of information from the following sources:
(a) AIRBUS FRANCE Company experience in designing cockpit HMI
(b) THALES AVIONICS Company experience in building and supporting HMI avionic systems.
(c) Involvement in FR-funded research projects such as PREFACE2 (Airport Navigation)
(d) Publications on NASA research programs related to airport surface operations (T-NASA).
(e) Aviation industry standard references; MOPS for the depiction of Navigation information on Electronic maps DO257A and Human Interface Criteria for Flight Deck Surface Operation Displays ARP 5898

The objective of the on-board A-SMGCS HMI as considered in the EMMA Phase 1 project is to provide an advisory aid to the pilots (that is, both the Pilot Flying (PF) and the Pilot Not Flying (PNF) / Pilot Monitoring (PM)) in the ground-operations phase of flight. Aircraft ground-operations comprise the landing roll, taxing and manoeuvring, and the take-off roll. There are many variables to be taken into account, but notably the HMI should provide intuitive information to the pilot with the following three aspects in mind.

The assumed domain for the A-SMGCS HMI is on multi-crew flight decks of civil transport aircraft and business jets (Section 5.4.1.2). It is intended that ground movement aids would be fitted into new aircraft in addition to retro-fitting to older aircraft (Section 5.4.3). In both instances, potential amendments to JAR25 and flight deck human factors certification (change to JAR25 to be proposed in September 2004) need to be considered.

REQ 4.2 - #1: Whatever HMI is implemented on a flight deck, the coherence between the information presented on the various cockpit displays and the real external environment shall be respected.

REQ 4.2 - #2: The onboard function for navigation on airport shall improve the situational awareness of the airport environment in order to help the flight crew to improve their mental representation of the airport layout relative to their own aircraft position.

REQ 4.2 - #3: The onboard function for navigation on airport shall provide the crew with an electronic moving map, on a cockpit display, positioned and oriented in relation to the own aircraft position and heading.

REQ 4.2 - #4: The airport moving map function shall present the own aircraft position to the flight crew.

REQ 4.2 - #5: Lights and information provided on Head-Down Displays shall be coloured.

REQ 4.2 - #6: The colour coding shall comply with the users stereotypes defined in Airworthiness Authorities regulations.

REQ 4.2 - #7: The colour coding shall be consistent throughout the applications in the cockpit.

REQ 4.2 - #8: Colours used for the HMI should be perceptible and differentiable by the pilot under the variety of lighting conditions expected in the work environment.

REQ 4.2 - #9: The HMI should support general surface movement situational awareness, the navigation and control (ATC) functions on airports.
REQ 4.2 - #10: The HMI should support control factors (Runway turn-offs to be used, appropriate speed control, braking performance, appropriate steering control), if the displayed data is reliable enough.

REQ 4.2 - #11: The HMI should support the crew in potentially hazardous situations and human error detection / resolution.

REQ 4.2 - #12: The HMI should include control means to adjust, manage or change the display and map information.

REQ 4.2 - #13: The HMI should be integrated with other display functions (whatever is the technical solution envisioned, i.e. existing cockpit display or standalone device) and should not interfere with any other flight deck functions.

REQ 4.2 - #14: The display function should be either stand alone or part of a multi-function display.

REQ 4.2 - #15: Functional priorities should be defined and form the basis of the layering of information.

REQ 4.2 - #16: Controls shall provide feedback when operated.

REQ 4.2 - #17: If a control can be used for multiple functions, the current function shall be indicated either on the display or on the control.
4.3 HMI requirements specific to Airbus flight deck

4.3.1 General Airbus flight Deck principles

Commonality is a feature of Airbus' new generation of jetliners, developed thanks to the introduction of fly-by-wire. The flight deck design that was launched by the A320 in 1984 introduced digital fly-by-wire for primary flight controls and sidesticks to commercial flight decks. The fly-by-wire technology that had matured for commercial operation by the 1980s has become the new standard for the crew-friendly environment of the future. It is the common standard for the A330, A340 and A380 flight decks.

SIDESTICKS

Another feature of Airbus cockpit is the introduction of the sidesticks with the benefit of an unobstructed view of the instrument panel and a slide-out working table in front of each pilot.

ECAM AND EFIS SCREEN DISPLAYS

Gone are the dozens of round instrument dials, now replaced by just six LCD screen displays. All six screens are fully display/function interchangeable and there are stand-by instruments as back up.

Four screens, two in front of each pilot, form the Electronic Flight Instrument System, while two central screens are the display part of the Electronic Centralized Aircraft Monitor (ECAM).

Four screens, two in front of each pilot, perform Electronic Flight Instrument System (EFIS) functions.

The outboard screens - Primary Flight Displays (PFDs) - carry data on a range of parameters including speed, altitude, aircraft attitude and heading. Current status of the Flight Management System (FMS)
is also shown. The inboard Navigation Display (ND) screens show data on the aircraft’s position and course. These may be displayed in selectable modes: Arc, Rose ILS, Rose VOR or Plan.

Two screens in the centre of the main instrument panel display information derived from the ECAM whose sensors throughout the aircraft keep systems under constant surveillance. The upper and lower screens - both manually and automatically - show engine and systems parameters and warnings.

CENTRE PEDESTAL CONTROL AND DISPLAY UNITS
Multipurpose Control and Display Units (MCDUs) are located on the central control pedestal. In addition to accessing the Flight Management System (FMS), these provide systems maintenance data in the air and on the ground. Failure messages can be printed out for later action or they can be transmitted ahead during flight to give advance warning of problems to be remedied on arrival.

4.3.2 Use of colour coding

REQ 4.3.2 - #1: The main colors of the Airbus standard colour palette that shall be used are as follows:

- Red,
- Amber,
- Green,
- Blue (Cyan),
- Yellow,
- White,
- Magenta.

REQ 4.3.2 - #2: The colour coding shall comply with the users’ stereotypes defined first in Airworthiness Authorities regulations, then with the Airbus aircraft commonality and finally with the aesthetic aspect.

*Note:* One important thing to note is that sometimes the HMI designer may be led to use a colour for a different purpose from the one it was initially intended:

- Either for discrimination purpose (e.g. on Navigation Display green colour is used for ADF symbology and White for VOR),
- Or by a process of elimination when neither green, amber, red… are appropriate.
- Or for contrast purpose (e.g. on Navigation Display the windshear indication, which stands for the highest degree of danger within the weather radar picture, is magenta coloured, whereas it should appears in red. Because a red message is concurrently displayed on the same picture, it would not have been legible).

REQ 4.3.2 - #3: As indicated in Airworthiness Authorities regulations, red shall be used only for indicating a hazard that may require immediate corrective action and amber shall be used only for indicating the possible need for future corrective action.

REQ 4.3.2 - #4: For background purpose, the colour used shall not compete with the foreground. The grey colour shall be preferred for background of data, text or symbol.

4.3.3 HMI requirements specific to A-SMGCS:

In this chapter, the onboard function for navigation on airports will be designated as the airport navigation function.

The airport navigation function is intended to be used as a complement to visual outside information, in conjunction with either electronically displayed maps and charts or operational documentation.
existing on board. (The function does not intend to replace the existing means of navigation on ground and is neither a primary nor the sole means to navigate on ground).

REQ 4.3.3 - #1: The use of the airport navigation function shall be implemented in an integrated manner into the flight crew’s tasks so as to provide acceptable workload at all times.

REQ 4.3.3 - #2: The airport navigation function shall be consistent with the Airbus cockpit philosophy, especially with the Navigation Display HMI guidelines.

REQ 4.3.3 - #3: The airport navigation function shall be usable by both pilots, Captain and First Officer, i.e. the cockpit displays used to present the electronic moving map shall be switchable in order to allow manoeuvring the aircraft from either pilot seat.

REQ 4.3.3 - #4: The airport navigation function shall be usable independently by Captain and First Officer in order to cope at any time with the pilots’ task sharing.

REQ 4.3.3 - #5: The Airport Moving map display shall be oriented in the A/C forward axis.

REQ 4.3.3 - #6: The airport moving map shall display the own aircraft symbol located and oriented relative to the background airport chart.

REQ 4.3.3 - #7: The magnetic heading shall be used to orientate the own aircraft symbol so as to be coherent with the airport charts orientation, especially in high latitudes.

REQ 4.3.3 - #8: The airport moving map shall provide a means to adjust the displayed range (individual zoom and pan functions) and to visualise the selected value of range.

REQ 4.3.3 - #9: The modes of presentation shall be consistent with the Airbus Navigation Display principles. Those modes shall be as follows:

- **ARC**: The own aircraft symbol is fixed and located at the bottom of the screen. The visible part of the map is the one located in front of the aircraft, in accordance with the range selected by the crew.
- **ROSE**: It is similar to the ARC mode except that the own aircraft symbol is centred on the screen, thus showing a 360-degree view of the airport chart, in accordance with the range selected by the crew.
- **PLAN**: The map is fixed on the display, “true north up” oriented and positioned at a given geometric point. The own aircraft is displayed according to its position (latitude/longitude) and oriented according to its heading.

REQ 4.3.3 - #10: The airport navigation function shall provide the flight crew with advisories to reduce the likelihood of infringements and runways incursion, navigation errors on airport surface, collisions with external elements, etc… Deviations from assigned routes shall be indicated and the flight crew shall get the appropriate advisories. The implementation of those advisories will depend on the considered A-SMGCS level (depending on both ground and airborne systems availability).

REQ 4.3.3 - #11: The airport navigation function shall provide a means to select the airport to be displayed.

REQ 4.3.3 - #12: The airport moving map shall present at least the following information on the displayed airport:

- The complete airport name, ICAO and IATA codes,
- The coordinates (latitude, longitude) of the aerodrome reference point
REQ 4.3.3 - #13: at least the following aerodrome features shall be labelled on the airport moving map:
- Runway
- Taxiway
- Parking area, Apron, stands and parking positions
- Control tower
- Aeronautical buildings (prominent buildings such as terminals, hangars which could be used as visual references)

REQ 4.3.3 - #14: For a given displayed range, all the labels shall remain readable during the airport moving map rotation.

REQ 4.3.3 - #15: In order to not clutter the electronic moving map, the labels shall be displayed according to the current selected range. For the highest ranges, only labels associated to the main airport structures shall be displayed whereas for the lowest ranges, all labels, linked to any airport elements of operational interest shall be displayed.

REQ 4.3.3 - #16: The own aircraft symbol shall be unobstructed.

REQ 4.3.3 - #17: The depiction of runways shall be distinctive from all other symbology.

REQ 4.3.3 - #18: If depicted, the taxi route information shall be distinguishable from all other map feature or attributes.

REQ 4.3.3 - #19: The runway identifiers shall always be legible on the display.

REQ 4.3.3 - #20: It should be necessary to consider benefits and limitation of each format and display medium:
- Head-up presentations, keeping the flight crew’s eyes focused outside, are more appropriate for presenting tactical information.
- Head-down displays with plan view, keeping the flight crew’s eyes into the flight deck are well suited for strategic information.

REQ 4.3.3 - #21: In case only head-down display is used, the display of information should be easily understood so as to minimize the time that crew attention is focused inside the flight deck.
4.4 HMI requirements applicable to other aircraft flight deck

Note: requirements included in this section have been compiled from information obtained from a number of sources. These sources include:

(a) BAE SYSTEMS Company experience in building and supporting complex avionic systems.
(b) Involvement in European-funded research projects such as MA-AFAS and ISAWARE II, as well as UK-funded projects such as SLATS (Safer Landing and Taxi System) and AFDT (Advanced Flight Deck Technologies).
(d) Reviews of the HMI requirements implicit in A-SMGCS references such as ED-87A, and the ICAO draft Manual on A-SMGCS
(e) Aviation industry standard references related to the design of HMI for complex avionic systems, including ARP 450D, ARP 1068B, ARP 4032A, ARP 5364, ARP 5365, FAA Order 8110-98.

4.4.1 Aircraft Flight Deck HMI Philosophy

The Boeing flight deck HMI philosophy has been to consider the aircrew as an integral and critical element of the aircraft with the final authority for operation and who are responsible for the safety of the flight. The Boeing view of human-centred aircraft system design is that this occurs when the system designer understands:

1. The roles and responsibilities of the aircrew,
2. The capabilities of the human in that role,

and uses a set of design guidelines that recognise and complement the roles, responsibilities and human capabilities. The allocation of final authority to the human crew is probably the largest difference in philosophy between Boeing and Airbus and has been reflected in statements such as (David Allen, Boeing): “If the airplane is structurally flyable, it must be controllable. Do not limit the control capabilities of the airplane below its structural limits” The McDonnell-Douglas flight deck HMI philosophy used in the design of the MD-11 (prior to the company’s acquisition by Boeing) was broadly similar to Boeing’s. Two notable differences were:

a) The introduction of a highly integrated (compared with contemporary aircraft) avionic system integrated by a single supplier (Honeywell). This allowed a greater degree of HMI and operating commonality between different aircraft system than had previously been possible.

b) Extended aircraft system fault diagnostic and remedial capabilities, which led to a more autonomous approach to crew involvement in reacting to system failures.

In addition, various airlines have adopted their own philosophies for line operation of their aircraft although, clearly, these must be in accordance with the capabilities of the aircraft and avionic systems supplied by the manufacturers. However, even with these differences in the underlying philosophy, a range of common flight deck HMI requirements for aircraft systems such as A-SMGCS can be identified.

REQ 4.4.1 - #1: There shall be uniformity of concept of HMI operation across different phases of flight and crew activities.

REQ 4.4.1 - #2: Visual display symbology and colour-selection rules – the A-SMGCS display colours and symbology should match those exhibited by the existing flight deck HMI (for example, on the Navigation Display).

REQ 4.4.1 - #3: Human-centric design process – aircrew should be involved in the system design and HMI specification from the inception.

REQ 4.4.1 - #4: Aircraft systems should be designed, and their associated HMI elements implemented such that the flight deck HMI is seamless (i.e. there is no apparent change in HMI philosophy as the crew task changes).
REQ 4.4.1 - #5: The flight deck HMI shall be designed to heighten crew awareness at every level.

REQ 4.4.1 - #6: The HMI shall be as simple as possible, reliable and maintainable.

REQ 4.4.1 - #7: In order to constrain crew workload, it may be necessary to prioritise / suppress warnings at certain stages of operation. The prioritisation of warnings should be based on the severity of the event (similar to those of EICAS/ECAM systems).

REQ 4.4.1 - #8: There shall be consistency of alert, caution and warning sounds and indications across the entire flight deck HMI and for all crew activities.

REQ 4.4.1 - #9: The selection of display method; format; consideration of head-down presentation versus head-up; refresh rate, etc. shall depend on the type of information displayed and role of the crewmember.

REQ 4.4.1 - #10: There may be a requirement to use additional audio cues to indicate critical events or changes.

REQ 4.4.1 - #11: Careful consideration shall be given to the type of information and parameters to be displayed (for instance, whether to display rate or state information). This also includes the identification and prioritisation of the different parameters to be displayed.

REQ 4.4.1 - #12: The flight deck HMI shall be tolerant to human error. If an error is made, the user must be made aware and a resolution must be attainable with minimal workload or delay. Errors should not be permitted to occur unnoticed.

REQ 4.4.1 - #13: The flight deck HMI shall be provided with display-interaction options, such as (in the case of a map display) zoom in / out and choice of orientation (for example north-up for planning, track-up when navigating around airport).

4.4.2 Crew Resource Management

There must be consistent crew responsibilities and operating procedures within the flight deck at different airports.

There must be consistency of procedures, roles and responsibilities between airborne and ground operations as A-SMGCS and ATM concepts develop (this implies a smooth development of operational procedures, both on the ground and in the air, as well as development of flight deck HMI concepts)

REQ 4.4.2 - #1: The flight deck HMI shall support consistent responsibilities, depending on crewmember role (PF, PNF/PM), in line with current / future operating procedures.

REQ 4.4.2 - #2: As a general principle, the flight deck HMI shall be developed to support the following crew roles: Pilot taxiing (PF) has eyes out of cockpit; PNF generally eyes out except for review of the taxi map (if presented on a head-down display) for situation awareness.

REQ 4.4.2 - #3: During ground operations, the flight deck HMI shall enable both pilots to be ‘in the loop’ with regards to where they are and the intended route.

4.4.3 Issues Relating to Aircraft Ground Movement
REQ 4.4.3 - #1: For ground movement operations, operational procedures shall clearly define, and the flight deck HMI should clearly support, the responsibilities of each crewmember.

REQ 4.4.3 - #2: The flight deck HMI shall support the crew’s general situation awareness (with respect to taxiway limitations, fixed obstructions, other aircraft, other ground vehicles, current position, taxi destination, etc.).

REQ 4.4.3 - #3: The operation of the A-SMGCS and its associated flight deck HMI shall be compatible with existing operator Standard Operating Procedures as well as the manufacturer recommending operating procedures.

REQ 4.4.3 - #4: The A-SMGCS and its associated flight deck HMI may provide additional information to support crew decision-making (decision aids) for activities such as:

- Taxi route selection and compliance with taxi clearance;
- Speed control during the taxi;
- Optimal braking on the landing-roll in order to exit the runway as planned, taking into account actual braking performance with current runway conditions.

REQ 4.4.3 - #5: The A-SMGCS and its associated HMI should be capable of being extended to support conflict detection (also possibly resolution) aids for use in poor visibility.

REQ 4.4.3 - #6: The A-SMGCS HMI shall take into account crew workload issues, such as:

- pre-departure pressures and
- post arrival ‘relief’ (following the potentially high workload descent / approach / landing stage).

The operation of the A-SMGCS and its associated HMI must not increase workload at these times, (for example it should require very little effort to initiate and operate the different system modes); indeed it should alleviate crew workload as far as is practicable.

REQ 4.4.3 - #7: The A-SMGCS and its HMI (both air & ground components) shall be designed to alleviate and/or minimise the impact of human error, particularly during the period of control-system change from ATC to ATM.

REQ 4.4.3 - #8: The A-SMGCS HMI shall provide a clear indication in the event of system failure and differentiate between this state and system status in a flight regime when the A-SMGCS is not used.

4.4.4 Issues Relating to Retrofit Installations

Consistency of operating procedures must be maintained before / after the installation of the retro-fit system; in the case of an A-SMGCS, a reversion capability must be provided to take into account equipment failure or landings at airports without automated ground support.

REQ 4.4.4 - #1: The HMI of retro-fit systems usually suffers from limited flight deck panel real estate – this can lead to the use of supplementary display devices, for example portable units. Care shall be taken to ensure that this does not lead to operational inconsistency between the retro-fit system and the rest of the flight deck HMI. In addition, the HMI of the retro-fit system must be designed so as not to clash or interfere with the HMI of existing systems.

REQ 4.4.4 - #2: Due care shall be exercise to ensure that the ability for a retro-fit system to access necessary aircraft data parameters does not adversely impact the quality of displayed information (in terms of timeliness, accuracy/precision, or completeness).
REQ 4.4.4 - #3: The HMI of the retro-fit system shall, as far as possible, be seamlessly integrated with the existing flight deck HMI mediums (for example the method of display control – soft keys or cursor control).

REQ 4.4.4 - #4: The potential change in the mandated approach to certification (human factors assessment and certification based upon the task-orientation of the whole flight deck, rather than each individual system within the aircraft) shall change the approach to retro-fit system design.
5 Implication of Human Factors HMI requirements on the EMMA project

This document is a collaborative effort of experienced individuals who provided their contributions in a document that compiles and tracks human factors issues. These Human Factors HMI issues are related to the development of both flight deck and air traffic controller systems to display and manage/monitor airport surface operations information.

The purpose of the document is to provide a central source for the tracking of human factors issues that affect the surface operations display system design. It will also serve as guide to future research activities, as well as a resource for the development of the systems that will be developed in the framework of the phase two of the EMMA project. This document is limited to identifying issues concerning human factored flight crew/ATC controller’s interfaces and does not address architecture issues.

The here-included requirements have been taken into account all along the different phases of the development of a given function, i.e. from the very first stage of the design to the verification and validations steps as follows:

- **Design**: The HMI requirements, as described in this document, for the different Human-Machine Interactions and/or functions that were developed in the EMMA framework, were spread into both operational and functional requirements, and were used as parent requirement for documents such as Functional Requirement Documents.

- **Verification**: It was checked that the HMI design fulfils the Human Factors related requirements. Before performing assessment sessions with end-users, it was checked that the HMI reached an acceptable level of compliance with respect to the HMI requirements.

- **Validation**: if some issues regarding the compliance of an HMI with respect to the requirements were still open, the validation stage enabled both HMI designers and HF specialists to consider again how to achieve the requirements in balancing the HMI requirements and the end-user needs. The validation phase was an important step where the requirements were either confirmed or reformulated.
6 ANNEX 1

6.1 References

[4] AS8034, SAE. MINIMUM PERFORMANCE STANDARD FOR AIRBORNE MULTIPURPOSE ELECTRONIC DISPLAYS, AEROSPACE STANDARD.
[5] ARP4256, SAE. DESIGN OBJECTIVES FOR LIQUID CRYSTAL DISPLAYS FOR PART 25 (TRANSPORT) AIRCRAFT, AEROSPACE RECOMMENDED PRACTICE.
[8] ARD50092 (7/24/2003), HUMAN FACTORS ISSUES ASSOCIATED WITH SURFACE OPERATIONS DISPLAYS, PREPARED BY THE G-10 COMMITTEE SURFACE OPERATION DISPLAYS SUBCOMMITTEE
[9] ARP5898 DRAFT VERSION 4.0 (2003) HUMAN INTERFACE CRITERIA FOR FLIGHT DECK SURFACE OPERATIONS DISPLAYS, DEVELOPED BY THE SAE G-10 SURFACE OPERATION DISPLAYS SUBCOMMITTEE
[12] EUROCAE (DECEMBER 2000), MINIMUM AVIATION SYSTEM PERFORMANCE SPECIFICATION FOR A-SMGCS, ED-87A

6.2 Definition of terms

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Shall</td>
<td>Sentences containing the word “shall” are mandatory practices. These sentences must be followed, without exception.</td>
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<tr>
<td>Should</td>
<td>Sentences containing the word “should” are strongly recommended practices.</td>
</tr>
<tr>
<td>Operator</td>
<td>The human being in control of a part of the A-SMGCS</td>
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### 6.3 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Long Name</th>
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<tbody>
<tr>
<td>A/C</td>
<td>Aircraft</td>
</tr>
<tr>
<td>AMAN</td>
<td>Arrival MANager</td>
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<tr>
<td>AOC</td>
<td>Airline Operation Communications</td>
</tr>
<tr>
<td>APP</td>
<td>Approach control</td>
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<tr>
<td>A-SMGCS</td>
<td>Advanced Surface Movement Guidance and Control System</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATCO</td>
<td>Air Traffic Controller</td>
</tr>
<tr>
<td>ATS</td>
<td>Air Traffic Services</td>
</tr>
<tr>
<td>DMAN</td>
<td>Departure MANager</td>
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<tr>
<td>ECAM</td>
<td>Electronic Centralised Aircraft Monitor</td>
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<tr>
<td>EFIS</td>
<td>Electronic Flight Instrument System</td>
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<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
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<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
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<tr>
<td>ILS</td>
<td>Instrument Landing System</td>
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<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
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<tr>
<td>MLAT</td>
<td>MultiLATeration</td>
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<tr>
<td>ND</td>
<td>Navigation Display</td>
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<tr>
<td>OCR</td>
<td>Optical Character Recognition</td>
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<tr>
<td>PFD</td>
<td>Primary Flight Display</td>
</tr>
<tr>
<td>PSR</td>
<td>Primary Surveillance Radar</td>
</tr>
<tr>
<td>QNH</td>
<td>Atmospheric pressure. Altimeter setting providing aircraft height above mean sea level</td>
</tr>
<tr>
<td>RWY</td>
<td>Runway</td>
</tr>
<tr>
<td>SCA</td>
<td>Surface Conflict Alert</td>
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<tr>
<td>SMR</td>
<td>Surface Movement Radar</td>
</tr>
<tr>
<td>SSR</td>
<td>Secondary Surveillance Radar</td>
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<tr>
<td>SWP</td>
<td>Surface Working Position</td>
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<td>TWR</td>
<td>Tower control</td>
</tr>
<tr>
<td>TWY</td>
<td>Taxiway</td>
</tr>
<tr>
<td>VOR</td>
<td>VHF Omnidirectional Range</td>
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