HUMAN-MACHINE INTERFACES FOR C4I2SR SYSTEMS

Lawrence Josuá Fernandes Costa, lawjosua@gmail.com
ITA – Instituto Tecnológico de Aeronáutica, Centro Técnico Aeroespacial, São José dos Campos – SP, Brasil
Carlos Henrique Quartucci Forter, forster@ita.br
ITA – Instituto Tecnológico de Aeronáutica, Centro Técnico Aeroespacial, São José dos Campos – SP, Brasil

Abstract. *This paper proposes a development process of human-machine interfaces for C4I2SR military defense systems based on the principles of the Usability Engineering. To accomplish that goal an elicitacion of the requirements that high complexity C4I2SR systems demand of their interfaces, along with the research and definition of the priorities for its development, such as the maximization of the situational awareness, was accomplished. These requirements were combined with the requirements of human-machine interfaces (HMI) focused on usability in order to develop a set of interface prototypes as a proposal for a C4I2SR system interface. At the end, usability evaluation methods were applied with highly positive results proving the success of the medtodology used.*

Keywords*: C4I2SR, situational awareness, interfaces, human-machine interfaces, usability.*

1 INTRODUCTION

The C4I2SR acronym, that combines the functions of “Command, Control, Communications, Computers, Intelligence, Integration, Surveillance and Reconnaissance”, refers to a group of functionalities and applications of a defense system that integrates the many levels of a military chain of command, including troops, armored cars, aircraft and surveillance ground stations, and the highest level of tactical and strategic information available in order to back up military decisions and actions. However nowadays C4I2SR systems include other areas as counter-intelligence, corporative information management and information warfare. These systems are designed to obtain advantages over adversaries not only on the battlefields but also on political or economic situations, supporting political initiatives with intimidation capability and offensive, defensive and support operations.

This group of information serves to the High Military Command or Heads of State as basis for strategic decisions that will rule the following events and actions on a strategic scenario and, therefore, need to be presented in a very logic way and with a highest level of perspicuity in a group of screens and monitors, and frequently updated. But how to assure this perspicuity and organization, considering the elevated amount of information and variables associated, is a question that may guarantee or not the success of a complex system like this. How must the interface between the user and the system be implemented? Or, assuming that these information will be presented on a group of monitors, how must the human-machine interface of a complex system like C4I2SR be implemented? This is exactly the question this paper plans to develop.

This paper has the purpose to accomplish a detailed study of the defense military system, C4I2SR, aiming the development of human-machine interfaces (HMI) for this system. Therefore, a study of the characteristics of usability focused human-machine interfaces was accomplished, taking as a base the Usability Engineering methodology, presented on section 2. On section 3, the requirements that complex systems like C4I2SR demands from its interface were collected, along with other priorities like situational awareness maximization. A research on the international norms and standards on interfaces and usability was also performed. Afterwards, a set of prototype interfaces was developed as an application proposal for C4I2SR systems, based on the principles and requirements collected on former chapters. In order to validate and assess the prototype interfaces, section 4 presents a research on the usability evaluation methods and applies the adequate methods on the developed prototype interfaces. Hence, this paper tries to validate the high usability interface development methods available.

2 HUMAN-MACHINE INTERFACES

On practically every technological solution, the capacity that a HMI has of making its system functionalities evident and automatically understandable may determine the acceptance of the whole solution by its target users. Usually, on a consumer point of view, the interface is the product, because the user experience with the interface is much more important to him than how the system works internally or how is it built.

This HMI capacity referred above is measured by a group of characteristics like ease of learning and productivity. These characteristics are grouped under the title of usability, or quality of use. The International Standards Organization ISO 9241 defines three components of quality of use applicable to the design of HMI:

- Effectiveness – Does the product do what the users require? Does it do the right thing?
- Efficiency – Can the users learn the HMI quickly? Can they carry out their tasks with minimum expended effort, including a minimum of errors? Does it improve the productivity/effort ratio? Does it do things right?

- Satisfaction – Do users express satisfaction with the product? Does the new product reduce stress? Do the end users now have a more satisfying job?

These characteristics are not intrinsic qualities of a product. The designer cannot physically measure an HMI and measure its effectiveness, efficiency, or satisfaction scores. Effectiveness will depend on the users' intentions, goals and tasks. Efficiency will depend on the users' understanding of the product and on their previous experiences. And satisfaction can only be expressed by the users. As a result, the unifying principle of design techniques that deliver usable products is that each recognizes the need to keep users at the center of the process. The overall design process that brings these techniques together is the work of authors like Nielsen (1993) and Shneiderman (1998) and is grouped under the title of Usability Engineering.

2.1 Usability Engineering

The Usability Engineering brings together a group of principles and techniques for the development of high usability interfaces, basing itself on a user-centered approach. The Usability Engineering has three main principles:

1- Know your users;
2- Involve users early and continually; and
3- Iterations and measurable targets.

The first principle highlights the necessity of knowing the end user deeply. An user-centered interface assumes that although people vary widely, they all have particular needs that must be met. User can often be a source of improvements and innovation, especially lead users and early adopters. The most difficult and demanding customers often become the best partners for product improvement, always criticizing and demanding quality.

Users should be the experts on their requirements. They know their goals, tasks, objectives and artifacts they produce and use, the work-arounds they invent (not just the official, formal procedures), and the problems they have. However, users are not always good at describing, explaining, or predicting their behavior. Because users do not often make good designers, they must be involved in effective ways, together with real designers. A successful HMI maps the users' conceptual model directly onto the software or hardware so that the users may not even be aware of the HMI components.

The first issue to be resolved is how to choose which users will be involved in the design. For consumer products, the answer will lie in the demographics of the target user population. For military productivity applications, target users are often easier to define but sometimes more difficult to access or to involve in the design process. For almost all products, there will not be a single user or user role. Although the end user, the "key presser" user, may be the primary person affected by the design, there will also be secondary users, like operation commanders. Therefore it is usual to conduct the project of the interface to more than one user role in order to include these secondary users. On some cases it is also useful to involve these secondary users on the conception and iterations of the design.

During the early gathering of information, designers will start to understand the users' range of concerns, goals and priorities, it is often helpful to develop a series of stereotypes, imaginary individuals whose life details and images are representative of the main user population. Developers and user alike can often relate to these portraits more easily than to dry statistics. These imaginary individuals can also star in the storyboards and scenarios that are used to gather users' requirements and explore solutions.

The second principle of Usability Engineering deals with the involvement of users on the design process of an HMI. Early design decisions are usually those concerning the product concept, its architecture and its priorities. As a result, these are the decisions that are the most costly to change later. If those decisions are not user-centered there is a great chance of a low usability product and low acceptance by the market and its consumers. For this reason, users should be involved as early as possible in the design process. Users usually contribute to early efforts to gather information through observation, questionnaires, focus groups, interviews, or more detailed task analysis. At this stage, designers will build models of the users' domain and establish task priorities and relationships.

Users are also better at criticizing an existing HMI than designing one from scratch. However, user involvement must be cost-effective. Simply placing users in front of a new application and asking for improvements will lead to a disconnected and unpriorized wish list. However, if on the beginning of the process these same users are presented to a number of alternative designs and are allowed to compare and criticize, they will be capable of highlighting its qualities and defects, and effectively contribute to the design. This is why prototyping is crucial, whether high-level or detailed, the alternatives will help the users to generate more ideas and also show that their comments are welcome and useful.

The third principle of Usability Engineering presents the iterative methodology and the utilization of measurable targets. The key to involving users is to take an iterative approach. Each iteration is an opportunity to bring in real users and evaluate different aspects of the evolving product. Early iteration prevents major architectural decisions from leading the development down erroneous and costly paths. Iteration should start as early in the development cycle as possible, with prototype designs that can be changed quickly. One potential downfall is that with iteration it is difficult to know when to stop. Each iteration must be focused on a desirable target and should improve the design. Usability metrics are the key, derived from an understanding of the users' priorities, the main tasks they carry out, and the desired productivity. Even if a development is limited in time, with a pre-specified number of main iterations, there should be some minimum usability acceptance criteria.

The basic Usability Engineering lifecycle contains four phases: an initial intensive requirements gathering phase is followed by a series of rapid iterations between prototyping and user testing or validation before final implementation. Field implementation then becomes a source of requirements for future products, and the cycle repeats.

There are three primary activities in the requirements gathering phase: user observation, interviewing and task analysis. Other techniques such as focus groups, questionnaires, and surveys, may be employed. This phase can produce large amounts of information, making it easy to lose sight of the main user priorities. Thus, one of the best techniques for ensuring continued focus on key user requirements is to capture main priorities in scenarios, vignettes or stories, which are taken from task analysis and observation.

On the prototyping phase, early prototypes are used to validate the designers' understanding of the users' domain and to explore design alternatives. These prototypes should be partial, cheap to produce and discarded frequently. Later prototypes are evolutionary and are gradually refined to become the finished product. Prototypes should be able to show a broad range of intended features and implementing the key ones in depth.

The two main challenges with a prototyping approach are, first, ensuring that each prototype is an improvement over the previous version and, second, knowing when to stop. In order to manage these issues, it is important to set minimum and desirable usability performance targets as well as limit dates for iteration. A prototyping approach allows the usability metrics to be monitored constantly.

The heart of the user-centered usability engineering process is the cycle between prototyping and evaluation. However, sooner or later the product is implemented and there is a greater investment in packaging, marketing, production, selling and maintenance. Continuing the product evaluation activities post-launch will also help capture any surprise issues as soon as possible and give quick feedback for the next version of the product.

3 INTERFACE DEVELOPMENT

The challenge on interface development is to be able to conciliate the characteristics and peculiarities of the C4I2SR system with the principles required to an HMI focused on a high usability level, besides conciliating with the existing recommendations and technical standards on human-machine interfaces. The result of this challenge is a set of prototype HMIs to start the Usability Engineering iterations aiming at a final high usability C4I2SR interface product.

Considering the characteristics of a C4I2SR system, a series of premises were established for its systems interface and were mandatorily persecuted during the HMI development. These premises were defined and organized by a series of meetings with C4I2SR systems developing specialists. The priority premises were grouped and are presented here:

- Since the system can be operated in several different platforms, ground stations, AEW&C aircraft, or battleships, it is required to define a goal to the development. Therefore, the focus of the interface development will be the set of screens presented to the operators on a ground command center since it is the most complete one.
- The system will be operated by trained military personnel, but its operation will cover from routine situations when in peace, to stressing situations as in wars. So, the interfaces shall minimize the negative effects of routine and stressful situations.
- The system shall be operated on a dedicated computer station and commanded by a single operator. Several operators may be simultaneously logged and connected to the system, but limited to one operator per station.
- The system shall be presented to the operator in a set of three high resolution color flat screen monitors. Limitations like the unavailability of the three screens shall be managed and the system shall function with the available resources.
- The system shall be fully operable through a three-button mouse, being possible to use keyboard shortcuts to access the systems functions.
- All the information and order between command centers and between command centers and military units shall be transmitted by the system through an encrypted data link, making radio communications optional and non-essential. The system is not required to contain radio communication capabilities.
- The system shall be accessible through a secure connection with the World Wide Web network after a series of successful identification and security authorization steps, assuring the confidentiality of the system information. The authenticity and security verifications shall be codified apart from the interfaces programming code.

Once defined the premises of C4I2SR system, the requirements that this system demands from its interface were studied. Therefore, bringing together the complex systems operation knowledge and the own peculiarities of the C4I2SR system, and also putting together system specialists and common target users to describe their actions over a proposed scenario, a group of operational and functionality requirements for interfaces was achieved, as follows:

- Considering the multi-platform characteristics of the system, the interfaces shall present a high level of system compatibility to adapt to these dissimilarities. Therefore, screen resolution shall be adaptable to the several existing possibilities in order to fully occupy the screen area.

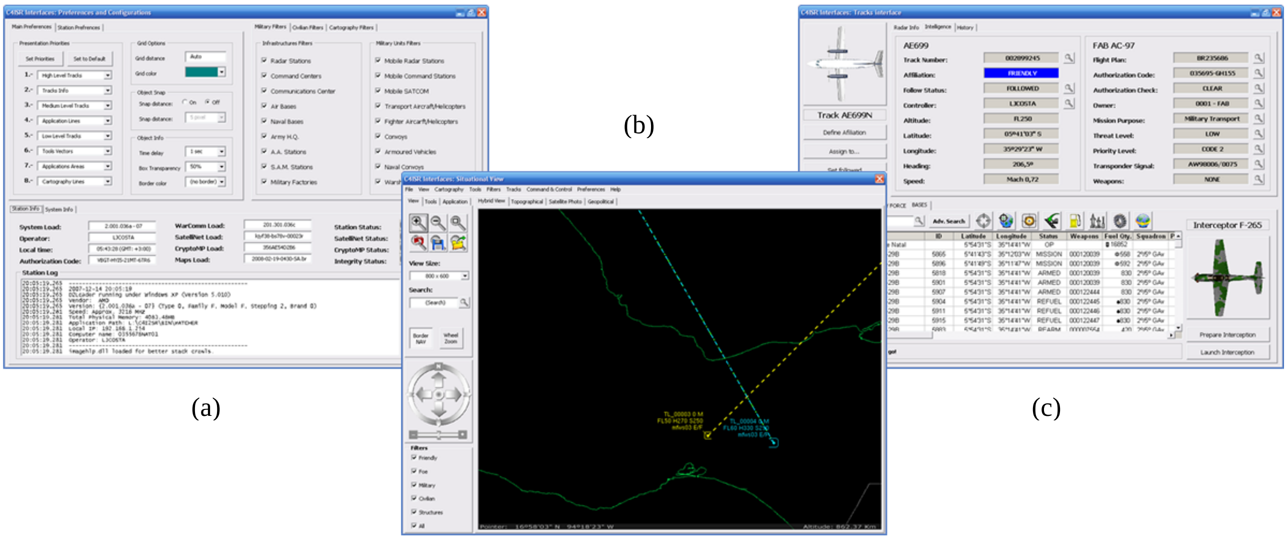
- Although operated by trained military personnel, the interfaces shall allow an easy learning of its functions and fast assimilation of its system's information. War periods may require operator substitutions on different levels of training, and even so this substitution must not significantly affect the performance of the system.
- Since the system shall be accessible through a secure connection to the internet network, the system interfaces must be compatible with the standards and protocols used on the World Wide Web.
- As a real time and high complexity system with huge amount of simultaneous information, the interfaces shall be based on graphical representations with cognitive interpretation to transmit its information, and only the physical attributes of each graphical representation shall be presented textually.
- Due to the huge amount of simultaneous information dealt by the operators on a C4I2SR, the interfaces shall focus on presenting permanently only important information crucial to the operators work.
- The access to the remaining information, the non-essential information, shall be reached on a simple and quick manner through a small number of proceedings or clicks and only when necessary.
- The screen area dedicated to the exhibition of the maps and radar signals shall be kept constantly visible and shall not be blocked by any window or interface menu.

3.1 Prototype Interfaces

Combining the studied premises and requirements of HMI development for the C4ISR system, with the norms and standards on usability like ISO 9241, ISO 14915 and military standard MIL-STD-1472F, with a group of best practices and ideas by usability working groups like the Multilateral Interoperability Programme, on Germany, and the Committee on C4I2SR for Future Naval Strike Groups, on USA, with the quality and potentials of some software interfaces considered by the users as being the best on software interfacing, it was developed a set of prototype interfaces as a proposal for C4I2SR systems.

From these best software interfaces on the market, it can be quoted the use of "Multi-layer Tabs" and "Dynamic Scenarios". The "Multi-layer Tabs" makes possible a quick access to functionalities and a high level of structure and organization of the system interfaces. Yet, the use of dynamic scenarios brings the capacity of transmitting a greater amount of information to the operator, modifying the presented information on the focused portion of the screen and hiding all the unnecessary information on the other portions of the screen. Therefore, a cleaner and more organized interface, with intuitive behavior, is obtained.

The developed set of prototype interfaces is divided on three main interfaces: the "Situational Interface", the "Tracks Interface" and the "Preferences Interface", shown on Figure 1. The following section will present a brief presentation on the developed interfaces, but the complete description and application is described on Costa (2008).



(a) (b) (c)

Figure 1 – Prototypes: (a) Preferences Interface; (b) Situational Interface; (c) Tracks Interface

3.1.1 The "Situational Interface"

The main screen of this interface set is the "Situational Interface", Figure 1(b). Placed on a central position between the other screens, the "Situational Interface" is responsible for presenting all the data and signal obtained from radars over a variety of map types, besides the shortcut to several functionalities that works over the interface itself or over the remaining screens. The "Situational Interface" screen is the one that concentrates the greater part of the operators attention and is the screen that allows the surveillance operations of the geographic region under the operator's responsibility.

The "Situational Interface" screen is subdivided on: Situational Area, Maps Menu, Navigation Compass, Filters Area, Shortcuts Area, and Main Menu. This subdivision is shown on Figure 2. It is important to highlight that on the contrary of window screens used by common software and systems, the "Situational Interface" does not have the functionalities of windows minimization or maximization. This happens because of the requirement of keeping the screen area dedicated to the exhibition of the maps and radar signals constantly visible.

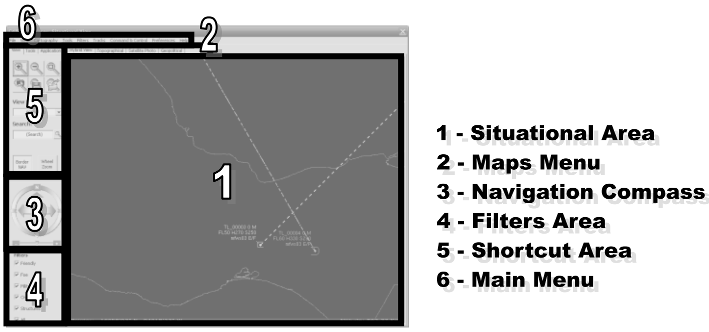


Figure 2 – Prototypes: Main Interface Subdivision

1 – The Situational Area (Figure 2 – Item 1) is the main area of the entire interface. It is on this area where the radar detected elements, or tracks, are presented over a map of the supervised region. All tracks movement as also its characteristics, attributes and behaviors are presented on this area, as also are all the track related functionalities, like interception paths, path history and evasion zones. On the bottom of the Situational Area, a status bar presents the operator with the latitude and longitude information of the mouse cursor on the map, as also the correspondent altitude to the selected zoom.

Map navigation can be done on the Situational Area itself by clicking and dragging the mouse button, besides the navigation through the Navigation Compass. Another navigation mode can be activated through the "Border NAV" button on the "View" tab of the Shortcut Area. On this navigation mode the operator can displace the map by positioning the mouse cursor on the edges of the screen, on the desired direction.

Each track has a number of attributes and characteristics associated to it. An aircraft, for example, has attributes as: track number, affiliation (allied, neutral or hostile), flight plan, altitude, speed and direction among others. These attributes must be presented to the operator beside the track symbol, having different priorities and importance to the operation of the system. These attributes are presented on the Situational Area inside the "track block", as shown on Figure 3(a).

The number of tracks that are to be presented on a screen depends exclusively of the situation that the monitored scenario is passing through at the moment and the operator has almost no control over it. In some war-like situations the tracks quantities being presented is so high that can by itself jam the visibility of the operator. If on those situations all the attributes of each track are presented inside its "track block", the visibility jam on the screen would make impossible the scenario acknowledgment by the operator, damaging his operations and making them inefficient and inaccurate. To avoid this problem on the developed interfaces it was applied a dynamic scenario solution, presenting attributes on demand. Meaning that, the less relevant attributes to the operation are to be show only when the operator focuses on the track. Therefore, the attributes presentation of each track works as follows:

- When a track is not selected or under observation (mouse cursor over it) only the essential information are exhibited on its "track block" (Figure 3(b));
- When a track is under observation, the essential information added of some complementary information are exhibited on its "track block";
- When a track is selected, all the essential and complimentary information are presented on its "track block" and the selected track is presented to the operator on the "Tracks Interface" (detailed ahead) along with every available information on the track (Figure 3(a)).

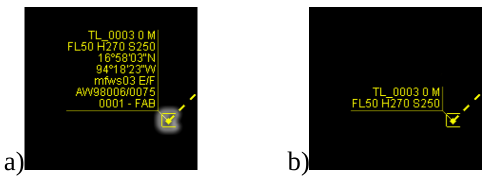


Figure 3 – Prototypes: Main Interface – COMPLETE AND REDUCED TRACK BLOCK

2 – Maps Menu (Figure 2 – Item 2). The operator has at his disposition several types of maps that can be visualized accordingly to the necessity. To alternate between the types of map the operator uses the Map Menu, which consists on a set of multi-layer tabs located right above the Situational Area. Therefore, the operator is capable of quickly alternate between the types of maps without loosing its attention of the Situational Area. Another way of accessing the several types of maps is through the Main Menu. The "Cartography" menu presents all the available types of maps that, when selected, alternate the presented Situational Area map besides exhibiting all configuration options about this map on the "Preferences Interface".

3 – The Navigation Compass (Figure 2 – Item 3) allows the operator to navigate on a precise way with fixed displacements. The name Navigation Compass comes from the external ring of the object, marked with an "N" that always points to the North direction and provides the direction sense to the operator. The "N" is actually a button the when pressed rotates the map until the north direction is exactly at the top of the screen, allowing a fast reference. On the inside of the compass there are four directional buttons, each one displaces the map according to the direction pointed and with a displacement proportional to the selected zoom. Between these buttons, a hexagonal joystick provides a similar displacement function but on a softer and slower way, for precise positioning.

Under the compass the zoom control can be found, responsible the zoom function of the Situational Area map. A plus (+) and minus (-) control with a rolling bar representing the maximum and minimum zoom allowed. By dragging the rolling bar cursor, the operator can rapidly adjust zoom positions when speed supersedes accuracy. This control can also be done by the mouse wheel, once the "Wheel Zoom" function on the "View" tab of the Shortcut Area is activated.

4 – The Filters Area (Figure 2 – Item 4) provides a fast and easy access to some of the most used filters used by the system operators. On this area the operator can select to hide elements from the Situational Area that are not relevant to the moment operation or surveillance, having only to unselect the group that is not required ate the moment. More filters options and Filters Area customization are accessible on the "Preferences Interface" through the "Filters' menu on the Main Menu.

5 – The Shortcut Area (Figure 2 – Item 5) is the region of the screen that concentrates the majority of the shortcuts to the C4I2SR system functionalities. It is subdivided on three tabs, each one containing a group of buttons representing the functionalities related to: exhibition and navigation – "View" tab, system tools – "Tools" tab, and programmed applications – "Application" tab. To this "Application" tab an example is the interception functionality. The Shortcut Area has the purpose of making the operators most used tools access quick and simple and therefore is customizable, allowing versatility on different operation types that requires different tools. All the functions found on the Shortcut Area are also found on the Main Menu.

6 – The Main Menu (Figure 2 – Item 6) organizes on categories all the available functions to the operator and keeps them close to the operator's attention on the main interface for fast access when required. It has a very intuitive behavior and is very similar to nowadays software menus. Some its categories are only presented to the operator when an object is selected. The Main Menu only list the several functionalities of the system, but once a functionality is selected, the screen that refers to this functionality is presented on one of the other screens: the "Track Interface" or the "Preferences Interface". Again, this happens because of the requirement of keeping the screen area dedicated to the exhibition of the maps and radar signals constantly visible.

3.1.2 The "Tracks Interface"

The "Tracks Interface", Figure 1(c), which is conventionally placed at the right side of the main screen, is the responsible for managing radar detected elements information, the tracks. The "Tracks Interface" is subdivided in two big parts: the Tracks Information Area, on the upper half of the screen, and the Military Units' Area, on the bottom half.

Every time a track is selected on the Situational Area of the main screen its information are presented on the Tracks Information Area. This area presents all the available information on the selected track and provides the operator with several frequently used functionalities.

On the Military Users' Area, the database with all national military units' status, from the nation that operates the C4I2SR, being ground, sea or aerial units, is presented. Besides the status of every military unit, information on the current position, embarked weapons, fuel quantities and other essential information are listed to the operator. This screen has access to the data obtained by the C4I2SR system communication means, and is capable of generating missions and orders to each military unit, like track interception or area patrol.

3.1.3 The "Preferences Interface"

The "Preferences Interface", Figure 1(a), is the responsible for allowing the operator to customize and personalize the several options and functionalities provided by the system and its interface. It is on this interface where all the presentation priorities are defined, where the automatic behaviors of the system are configured, where the details of the filters are accessed and selected and where the shortcuts of the main screen are customized. Besides that, this interface is also responsible for the exhibition of the system status and events, from initialization log to war operations records.

4 VALIDATION AND EVALUATION

In order to perform a usability assessment of the proposed interfaces, an elicitation on the literature evaluation methods, which are already successfully established on previous studies and specialist analysis, was performed. Several methods and approaches were found and criteria had to be defined to select the most adequate ones.

The evaluation method selection must take on account all the costs, number of involved personnel, deadlines and expected accuracy. The ergonomic approach suggests the constant evaluation, on all the product lifecycle. In the search for a high level of users' needs satisfaction, evaluation methods can be applied on the development processes.

Considering that the proposed interfaces are on a initial phase of development, the low availability of resources and personnel, and also the reduced deadline to tests execution, it's correct to conclude that the most indicated method to be applied on the proposed C4I2SR system interfaces is the evaluation through Specialized Revisions, using heuristics evaluation methods, consistency inspections and mainly cognitive navigation - The usability evaluation method selection is detailed described on Costa (2008). As a result, the evaluation of the proposed interfaces was organized as follows.

First, C4I2SR system specialists were introduced to a presentation of the proposed prototype interfaces and involved functionalities. Detailed and functional descriptions of the interfaces were transmitted to the specialists to guarantee the understanding and assimilation of the following evaluation steps.

Once the interface proposal was assimilated, the system specialists were immersed on the system operation through cognitive navigation, where they could follow all the interactions between the operator and the system during a predefined series of events on a representative vignette.

On the end, the specialists were subjected to formal interviews where they were invited to freely opine about some directed questions contained on a questionnaire based on the ISONORM 9241/10 model, from Prumper (1993). This questionnaire divides questions on seven sections, accordingly to the principles of dialogue on part 10 from ISO 9241:

- Principle I: Task Suitability: Evaluates if the software gives the user sufficient support for an efficient and effective execution of the tasks.
- Principle II: Self-description: Evaluates if each step of the program is immediately understandable through system feedbacks or demanded explanations.
- Principle III: Controllability: Evaluates if the software allows user to start and control the rhythm and direction of the interactions.
- Principle IV: Accordance with Users Expectations: Evaluates if the software is consistent and corresponds to the individual characteristics of the user, like tasks, knowledge, education, experience and usually accepted conventions.
- Principle V: Fault Tolerance: Evaluates if the software complies with the expected results although evident input errors, requiring none or minimal corrective actions by the user.
- Principle VI: Individualization Support: Evaluates if the software is easily modified to adapt itself to the needs of the user's tasks, preferences and individual experiences.
- Principle VII: Learning Suitability: Evaluates if the software supports and guides the user on the learning process of the system.

Although each of the ISO 9241/10 principles have a different quantities of recommendations, it was established a limit of five questions for each principle. According to Prumper (1999), the objective of this limitation is to reduce the filling time and keep the results coherence.

4.1 Results and Comments

The questionnaire answers are separated on two poles, the left one describes the negative extreme, and the right one describes the positive extreme. The possible values for the answers vary between '---' and '+++' (coded in an interval between 1 and 7), requiring the evaluator to mark the option the he considers the most adequate on his assessment. The language used is intended to be the most familiar as possible to the operation and to the task.

The questionnaire was subjected to the evaluation of two C4I2SR system specialists:

- Engineer Robim Norihito Furukita, specialist on C4I2SR system development, with vast experience on the operational area and on the interface development.
- Engineer Luiz Ferreira da Rocha Filho, specialist on C4I2SR system development, with vast experience on complex systems operation, wide knowledge on the operational needs of C4I systems and interface development.

The questionnaire that was subjected to each specialist is presented on Table 1, structured according to the dialogue principles of part 10 from ISO 9241 norm. The obtained results, some comments and discussions are presented on the following sections. The symbolization used on the questionnaire filling is below:

○ Eng. Robim Norihito Furukita × Eng. Luiz Ferreira da Rocha Filho

Table 1 – ISONORM 9241/10 and answers

	Principle I: Task Suitability							
The interface...	- - -	- -	-	+/-	+	++	+++	
Is complicated to use. Does not offer all the necessary functions to efficiently execute the tasks.					⊗			Is easy to use. Offers all the necessary functions to efficiently execute the tasks.
Offers poor resources to automate repetitive tasks.					⊗			Offers good resources to automate repetitive tasks.
Requires unnecessary data input.					×	○		Does not require unnecessary data input.
Is inadequate to the works needs.					⊗			Is adequate to the works needs.
	Principle II: Self-description							
The interface...	- - -	- -	-	+/-	+	++	+++	
Provides a low notion of its functions capability.					○	×		Provides a good notion of its functions capability.
On the menus, uses difficult to understand terminology, abbreviations or symbols.						⊗		On the menus, uses easy to understand terminology, abbreviations or symbols.
Insufficiently indicates which inputs are allowed or necessary.					×	○		Sufficiently indicates which inputs are allowed or necessary.
Does not provide context sensitive explanations when demanded.				⊗				Provides context sensitive explanations when demanded.
Does not provide context sensitive explanations automatically.				⊗				Provides context sensitive explanations automatically.
	Principle III: Controllability							
The interface...	- - -	- -	-	+/-	+	++	+++	
Offers few possibilities of work interruption at any point and resuming it later ate the same point without data loss.			⊗					Offers good possibilities of work interruption at any point and resuming it later ate the same point without data loss.
Forces the user to execute a rigid and unnecessary sequence of steps.					⊗			Does not force the user to execute a rigid and unnecessary sequence of steps.
Does not easily support skin and menus customization.				×		○		Easily supports skin and menus customization.
Is projected in a way that the user cannot customize the presented information and how this information is presented.					×	○		Is projected in a way that the user can customize the presented information and how this information is presented.
Generates unnecessary interruptions to the workflow.						⊗		Does not generate unnecessary interruptions to the workflow.
	Principle IV: Accordance with Users Expectations							
The interface...	- - -	- -	-	+/-	+	++	+++	
Complicates the users' orientation due to an un-patterned interface design.					⊗			Eases the users' orientation due to a patterned interface design.
Does not provide feedback on successful or not inputs.				×	○			Provides feedback on successful or not inputs.
Provides insufficient feedback on the current processing.				○	×			Provides sufficient feedback on the current processing.
Has an unpredictable response time					⊗			Has a predictable response time.
Is not designed under a consistent and patterned principle.						×	○	Is designed under a consistent and patterned principle.
	Principle V: Fault Tolerance							
The interface...	- - -	- -	-	+/-	+	++	+++	
Is designed with small errors causing severe consequences.				⊗				Is designed with small errors not causing severe consequences.
Takes too long to inform about input errors.				×	○			Immediately informs about input errors.
Provides hard to understand error messages.			×		○			Provides easy to understand error messages.
	Principle VI: Individualization Support							
The interface...	- - -	- -	-	+/-	+	++	+++	
Is hard to expand with upcoming new functionalities.				⊗				Is easy to expand with upcoming new functionalities.
Is hard to adapt to the individual style of work.					×		○	Is easy to adapt to the individual style of work.
Is not equally adequate to new users and experienced users because it is hard to adapt to the knowledge level of the user.					×		○	Is equally adequate to new users and experienced users because it is hard to adapt to the knowledge level of the user.
Is, inside its scope, hard to adapt to different tasks.					×		○	It is, inside its scope, easy to adapt to different tasks.
Is designed in a way that the interface is difficult to adapt to the individual needs of the users.					×		○	Is designed in a way that the interface is easy to adapt to the individual needs of the users.

	Principle VII: Learning Suitability							
The interface...	- - -	- -	-	+/-	+	++	+++	
Requires lots of time to learn how to use.					×	○		Requires few time to learn how to use.
Does not encourage experimenting new functions.				×		○		Encourages experimenting new functions.
Requires lots of details memorization.					×	○		Requires few details memorization.
Is designed in a way that what is learned is hardly memorized.					×	○		Is designed in a way that what is learned is easily memorized.
Is hard to learn without external help or manuals.						⊗		Is easy to learn without external help or manuals.

4.2 Evaluators Comments

Adequacy and usability are directly connected to the clients needs. Eng. Rocha.
The needs vary accordingly to the immersed context. Eng. Rocha.
Good visibility of the basic functions. Eng. Rocha.
It would be interesting to use explanation texts to the commands. Eng. Rocha.
It must contain the commands: context save and context restore. Eng Rocha.
It is not clear on how to save images from configurations. Eng Robim.
Good operative sequence. Eng. Rocha.
Missing error messages. Eng. Rocha.
Good standardization. Eng. Rocha.
Errors consequences not observed. Eng Rocha.
Friendly interface with good scalability. Eng. Rocha.
Excellent visualization and individualization support. Eng Robim.

The evaluators were capable of making a complete analysis of the interface. The comments obtained show some improvements that can be applied on next iteration. Good results on visibility, standardization, individualization and operative sequence were achieved. It is important to make clear that each client may have different desires and different needs, therefore the interface must be adaptable and customizable. As an initial prototype for the system interface, it shows a variety of functions, but detailing only the most important procedures, therefore only the final interface can be fully evaluated on adequacy. No error messages were included on this version and are to be implemented on further iterations.

About the "context save and restore" and "image save and restore" functions the interface provides this functions within the menu File on the Main Menu, but it may be modified to a more accessible position. The explanation texts suggested are to be implemented, on posterior iterations, as Tool Tips when to operator stops a while over a button.

4.3 Additional Comments

Besides the questions directed by the ISONORM 9241/10 questionnaire, the specialists were encouraged to speech their opinions and observations freely about the proposed interfaces. A summary of the obtained comments is presented below.

- *The Navigation Compass, the Filters Area and the Shortcut Area could have the capacity to be hidden, allowing the experienced operator to maximize the Situational Area and use the commands through keyboard shortcuts.*
- *The Multi-ABAS layout on the Shortcut Area and also on the Maps Menu is practical and allows a high level of organization to the operator. The interfaces are well patterned with this layout.*
- *The Filters Area could also use the Multi-layer Tab layout used on the Shortcut Area, providing the operator a greater range of filters options organized in tabs like: application, source, category and others.*
- *A very useful information that can be included on the "View" submenu of the Main Menu is the centralize object vision function. The object could be a track and also a user-inserted point.*
- *The requirement of not obstructing the Situational Area with windows and menus was well incorporated and applied, guaranteeing constant visualization of the supervised elements by the operator.*
- *A functionality that is present on several complex systems interface and could bring great benefits to this interface is the utilization of pop-up menus, which presents object specific functionalities.*
- *The way the operators attention is called whenever a new element is detected by the radars, using wave effects aural warnings, holds quite well to the function it is destined.*
- *The symbolization used to identify system tracks (formed by several radars data fusion) is clear, objective and transmits all the necessary information without overloading the interface.*
- *Focusing on the self-description principle of ISO 9241/10 norm, it would be necessary to include a precise description of all available functionalities on the interface. This can be done through the use of Tool Tips, which*

presents a brief description of the functionality when the operator maintains the mouse cursor over a button for a few seconds. The tool tips delay must be fully customizable.

5 CONCLUSION

This work performed a detailed research on the military defense system C4I2SR, its operation and working modes, with the focus of collecting its peculiarities and system requirements to a human-machine interface. The main demands of the system, like situational awareness, were analyzed and defined as priority during the development of a set of human-machine interfaces for the C4I2SR system focused on usability. To develop this interfaces all the intrinsic characteristics of high usability interfaces were analyzed, focusing on maximizing the efficiency, efficacy and satisfaction on the operation of the system by its target user, a military operator. From this collected information a second group of requirements and optimization procedures was generated for the interfaces. A third group of requirements and recommendations was obtained from the elicitation of the norms and international standards on interfaces and usability.

Combining and applying all these requirements groups, a set of prototype interfaces was developed for the C4I2SR system. These interfaces were subjected to a simulated war scenario, allowing the operations sequence and behavior observation of the proposed interfaces. On this way, it was possible to show the viability of the application of the international norms and recommendations to complex systems and even on exclusively military applications like C4I2SR system. The proposed interfaces were considered adequate for an initial prototype and were tested by some command, control and surveillance systems specialists in an evaluation procedure.

The evaluation methods were selected after a series of qualitative studies on the available literacy methods, pointing to the ones best adapted to an interface on initial development phase. The ISONORM questionnaire and the cognitive navigation generated high quality results under the specialists' evaluation, bringing up ideas and proposals to increase further more the usability of the proposed interfaces.

This cycle closes the first iteration on the human-machine interfaces development for C4I2SR systems and concludes the scope of this paper. The objective of studying the initial steps of an interface development and assess its application proposing a set of interfaces for the complex military C4I2SR system was achieved and the quality of its results were able to be verified with pre-validated methods. The interface development process may yet have several iterations, until a high quality final product is obtained.

6 REFERENCES

COMMITTEE ON C4ISR FOR FUTURE NAVAL STRIKE GROUPS (National Research Council). C4ISR for Future Naval Strike Groups. Washington, 2006.

Costa, Lawrence J. F. Interfaces Homem-máquina para Sistemas C4I2SR. Mastering degree thesis on Instituto Tecnológico de Aeronáutica. São José dos Campos: 2008

ISO 9241 "Ergonomic Requirements for Office Work with Visual Display Terminals" - ISO Technical Committee 159, Signals and Controls Group 4, Working Group 5 (TG159/SC4/WG5)

ISO 14915 "Software Ergonomics for Multimedia User Interfaces" - ISO Technical Committee 159, Signals and Controls Group 4, Working Group 5 (TG159/SC4/WG5)

MIL-STD-1472F "Human Engineering" – Department of Defense Design Criteria Standard, 2003

Multilateral Interoperability Programme (Alemanha). The C2 Information Exchange - Greding, 2005. (Edition 6.15e).

Nielsen, J. & Molich R. Heuristic Evaluation of User Interfaces. In: Proceedings ACM CHI´90 Conference. Seattle, 1990.

Nielsen, J. Usability Engineering. London: Academic Press, 1993.

Nielsen, J. & Mach, R. Usability inspections methods. EUA: John Wiley & Sons, 1994

Nielsen, J. Usability Laboratories: a 1994 survey (http://www.useit.com/papers/uselabs.html) - acessado em 26/06/2007.

Oppermann, R. & Reiterer, H. Software evaluation using iso 9241 evaluator. Behaviour & Information Technology, v.16, n. 4/5, 1997.

Prumper, J. Software-evaluation based upon iso 9241 part 10. In: Vienna Conference, VCHCI´93. Viena: 1993.

Prumper, J. Test it: ISONORM 9241/10. In: HCI International ´99. 1999

Shneiderman, B. Designing the User Interface: strategies for effective human-computer interaction. 3. ed. EUA: Addison-Wesley, 1998

7 RESPONSIBILITY NOTICE

The author is the only responsible for the material included in this paper.