INCOMMANDS TDP

Development of Decision Aid Implementation Guidance for the INCOMMANDS Human Factors Design and Evaluation Guide

Simon Banbury
Michelle Gauthier

CAE Professional Services
1135 Innovation Drive, Suite 200
Kanata, ON
K2K 3G7

Project Manager: Simon Banbury [+1 613 247 0342]

Contract number: W7701-04-3544/001/QCL

Contract Scientific Authority: Sharon McFadden, (416) 635 2189
Human Systems Integration Section, DRDC Toronto

Defence R & D Canada - Toronto

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Author

Simon Banbury

Author

Michelle Gauthier

Approved by

Sharon McFadden

Scientific Authority

Approved for release by

K. M. Sutton

Chair, Document Review and Library Committee

Abstract

The INCOMMANDS TDP seeks to research, demonstrate and evaluate new command decision support concepts for the HALIFAX Class frigate's command and control (C^2) system, with the objective of improving team battlespace awareness, and increasing decision speed and accuracy. The aim of this document is to support the design and development of Operator Machine Interface (OMI) concepts developed as part of the INCOMMANDS TDP by providing a structured and comprehensive set of design guidelines which address decision aiding concepts specifically. The guidance within this document will be integrated within a final document, the INCOMMANDS Human Factors Design and Evaluation Guide, which will cover both OMI and decision aid guidance.

Résumé

Le PDT INCOMMANDS cherche à mettre au point, à et à évaluer les nouveaux concepts de soutien à la décision du commandement (SDC) pour le système de commandement et de contrôle (C^2) de la frégate de la classe HALIFAX dans le but de sensibiliser davantage les équipes à ce qui se passe sur le terrain et de permettre une prise de décision plus rapide et éclairée. Le présent document vise à appuyer la conception et l'élaboration des concepts d'interface opérateur-machine (IOM) élaborés dans le cadre du PDT INCOMMANDS en fournissant un ensemble structuré et complet de lignes directrices relatives à la conception traitant particulièrement des concepts d'aide à la décision. Les directives contenues dans le présent document seront intégrées dans un document final, le Guide de conception et d'évaluation tenant compte des facteurs humains - INCOMMANDS, qui couvrira les directives relatives à l'IOM et à l'aide à la décision.

Executive Summary

The INCOMMANDS TDP seeks to research demonstrate and evaluate new command decision support concepts for the HALIFAX Class frigate's command and control (C^2) system, with the objective of improving team battlespace awareness, and increasing decision speed and accuracy.

The intention of this document is to support the design and development of Operator Machine Interface (OMI) concepts developed as part of the INCOMMANDS TDP by providing a structured and comprehensive set of design guidelines which address decision aiding concepts specifically. The guidance within this document will be integrated within a final document, the INCOMMANDS Human Factors Design and Evaluation Guide, which will cover both OMI and decision aid guidance. This work was completed under contract to DRDC-Toronto.

The goal of the work produced as part of Task 6, Human Factors Investigations Support, of contract W7701-4-3544, is to inform and guide the design and development of the OMI concepts explored and implemented within the INCOMMANDS TDP. In order to achieve this goal, the objectives of this report are as follows:

- To incorporate recommended standards and guidelines that will guide and inform the design of OMI and decision aiding concepts developed within the INCOMMANDS project so that they are consistent with Human Factors best-practice;
- To provide common OMI design guidance for existing decision aids, decision aids under development, and future decision aiding concepts, within the context of Maritime Command and Control (C2), including Threat Evaluation and Weapons Assessment (TEWA); and,
- To provide guidance, in terms of metrics and tools, for the evaluation of the OMI's compliance with the proposed guidelines.

The structure of the guidance pertaining to the design of decision aids within this document will follow a *Perceive-Decide-Act* classification of decision aiding (and related) technologies. The first section comprises guidance relating to Electronic Support System (ESS)-specific OMI design goals. The next section is devoted to specific guidance relating to specific classes of decision aids; Information Management Aids (guidelines to optimise and organise the information presented for efficient information acquisition and synthesis), Decision Making Aids (guidelines to support efficient and effective decision making), and Control and Action Aids (guidelines to minimise operator out-of-the-loop problems). Finally, the last two sections cover guidelines relating to Design and Evaluation, and Training and Implementation.

The format of the Human Factors guidelines presented within this document was designed to impose a consistent and logical format to assist the reader in finding the relevant guideline(s) quickly. Each and every guideline is composed of the following categories:

- *Guideline Number*. A unique reference number given to each guideline, or set of guidelines, to enable rapid searching for a particular guideline.
- *Guideline Title*. A short title that summarizes the topic of the guideline(s).
- *Source*. A reference for the source document(s) from which the guideline(s) was (were) taken from.
- *Guideline(s)*. A list of guidelines relevant to the topic. These are worded as 'shall' (i.e., mandatory) statements.

- *Discussion*. Where relevant, supporting evidence for, and/or further discussion of, each guideline is presented in this section.
- *Evaluation Measures and Methodology*. Evaluation measures and methodology are provided to determine compliance with the guideline(s). Evaluation measures relate to *System Performance, Task Performance, Operator Situation Awareness*, *Operator Workload*, *Operator Trust,* and so on. The exact criteria to which the components of the OMI are evaluated against (e.g., the extent to which the OMI affords adequate Situation Awareness or workload 'levels') should be determined on a case-by-case basis; as such, it is beyond the scope this document to provide exact values, or thresholds, to each and every evaluation criteria mentioned. The evaluation measures described in section 3.2 of this report can be administered by the following methodologies: *Inspection* (e.g., a visual inspection to determine that menu structure is compliant with guidelines, or visual measurement of font size to determine compliance); *Demonstration* (e.g., a walk-through by a Human Factors professional, to determine that uncertainty information regarding system advice is compliant with guidelines); and *Experimentation* (e.g., modeling or simulation activities, or a human-in-the-loop experimental or questionnaire-based study, led by a Human Factors professional, to determine that the system promotes acceptable levels of operator workload).
- *Relationship to Other Guidelines*. Relevant guidelines (and the Guideline Number) to the topic are presented here. Cross-referencing should make it less likely that related guidelines are overlooked.

The guidance within this document does not present detailed design solutions or exact specifications. As well as proving to be technically difficult, time consuming and prone to obsolescence over time, to do so would inhibit the creative scope of the development team. Instead, the document presents generic guidance to support the development of decision aiding concepts. The detailed design solutions will be developed and evaluated by the development teams using, in part, the evaluation criteria provided in here. As successful solutions are developed, they should be captured as design specifications and added to the guidance provided in this document. Finally, each project related to the development of decision aids for Maritime C^2 should refer to the guidance presented in this document or eventually to the INCOMMANDS Human Factors Design and Evaluation Guide. In doing so, consistency across all systems that are being developed should be achieved.

The vast majority of evaluation measures described within this document require some form of human-in-the-loop experimentation. This is due to a combination of the imprecision of the constructs that need to be measured (e.g., Situation Awareness, workload and trust), the imprecision of the measurement tools used to measure these constructs, and the imprecision of the guidelines themselves. It is therefore imperative that any lessons learnt from one OMI development project should be shared with the wider community.

Sommaire

Le PDT INCOMMANDS cherche à mettre au point, à expérimenter et à évaluer les nouveaux concepts de soutien à la décision du commandement (SDC) pour le système de commandement et de contrôle (C^2) de la frégate de la classe HALIFAX dans le but de sensibiliser davantage les équipes à ce qui se passe sur le terrain et de permettre une prise de décision plus rapide et éclairée.
Le présent document vise à appuyer la conception et l’élaboration des concepts d’interface opérateur-machine (IOM) élaborés dans le cadre du PDT INCOMMANDS en fournissant un ensemble structuré et complet de lignes directrices relatives à la conception traitant particulièrement des concepts d’aide à la décision. Les directives contenues dans le présent document seront intégrées dans un document final, le Guide de conception et d'évaluation tenant compte des facteurs humains - INCOMMANDS, qui couvrira les directives relatives à l’IOM et à l’aide à la décision. Ces travaux ont été réalisés en vertu d’un marché avec RDDC Toronto.

L’objectif des travaux produits dans le cadre de la tâche 6, soutien aux enquêtes relatives aux facteurs humains, du marché W7701-4-3544 consiste à informer et à guider la conception et l’élaboration des concepts d’IOM analysés et mis en œuvre dans le PDT INCOMMANDS. À cette fin, les objectifs de ce rapport sont les suivants :

- Intégrer des normes et des lignes directrices recommandées qui guideront et façonneront la conception des concepts d’IOM et d’aide à la décision élaborés dans le cadre du projet INCOMMANDS, de sorte qu’ils correspondent aux meilleures pratiques des facteurs humains;
- Assurer une direction commune en matière de conception d’IOM en ce qui touche les aides à la décision actuelles, les aides à la décision en conception et les concepts d’aide à la décision futurs dans le contexte de commandement et contrôle (C2) de la Marine, comprenant l'évaluation de la menace et la désignation des armes (TEWA);
- Fournir des directives en ce qui touche les mesures et les outils au niveau de l’évaluation de la conformité de l’IOM aux lignes directrices proposées.

La structure des directives relatives à la conception des aides à la décision dans le présent document suivra une classification *Perceive-Decide-Act* des technologies d’aide à la décision (et technologies connexes). La première partie comprend des directives liées aux objectifs de conception d’IOM propre au SSE. La partie suivante est consacrée aux directives précises relatives aux catégories d’aides à la décision particulières suivantes : aides à la gestion de l'information (directives en vue d’optimiser et d’organiser l’information présentée afin que l’acquisition et la synthèse de l’information soient efficaces), aides à la prise de décisions (directives en vue d’appuyer une prise de décision efficace) et aides au contrôle et à la gestion (directives en vue de réduire les problèmes qui dépassent l’opérateur). Enfin, les deux dernières parties couvrent les directives relatives à la conception, à l’évaluation, à la formation et à la mise en œuvre.

Le format des lignes directrices relatives aux facteurs humains présentées dans ce document a été conçu pour imposer un format logique et uniforme de façon à aider le lecteur à trouver rapidement la(les) ligne(s) directrice(s) pertinente(s). Toutes les directives, sans exception, regroupent les catégories suivantes :

- *Numéro de la ligne directrice*. Numéro de référence unique attribué à chaque ligne directrice, ou à un ensemble de lignes directrices, pour effectuer une recherche rapide.

- *Titre de la ligne directrice*. Court titre résumant le sujet de la ligne directrice.
- *Source*. Référence au document source à partir duquel la ligne directrice a été tirée.
- *Ligne(s) directrice(s)*. Liste des directives se rapportant au sujet. Il s'agit également d'« obligations » puisque l'on doit y donner suite.
- *Discussion*. Lorsque pertinent, des preuves ou des discussions supplémentaires concernant chaque directive sont présentées dans cette partie.
- *Méthodes et mesures d'évaluation.* Les méthodes et mesures d'évaluation sont fournies afin d'établir la conformité avec les lignes directrices. Les mesures d'évaluation se rapportentau rendement du système, à l'exécution des tâches, à la connaissance de la situation, de la charge de travail et à la confiance manifestées par l'opérateur, et ainsi de suite. Les critères exacts d'après lesquels les composantes de l'IOM sont évaluées (p. ex., dans quelle mesure l'IOM assure une bonne connaissance de la situation ou des « niveaux » de charge de travail adéquats) doivent être établis au cas par cas. À ce titre, la portée de ce document n'est pas de fournir les valeurs ou les seuils exacts pour tous les critères d'évaluation mentionnés. Les mesures d'évaluation décrites dans la partie 3.2 de ce document peuvent être administrées par les méthodes suivantes : *Inspection* (p. ex., une inspection visuelle visant à déterminer si la structure du menu est conforme aux lignes directrices ou une mesure visuelle de la taille de la police visant à vérifier la conformité), *Démonstration* (p. x., une révision structurée effectuée par un professionnel de l'ergonomie afin de vérifier si les incertitudes quant aux conseils relatifs au système sont conformes aux lignes directrices) et *Expérimentation* (p. ex., activités de modélisation ou de simulation, ou une étude expérimentale tenant compte de l'élément humain ou basée sur un questionnaire, effectuées par un professionnel de l'ergonomie afin de déterminer si le système fait la promotion de niveaux de charge de travail acceptables pour l'opérateur).
- *Relation avec les autres lignes directrices*. Les lignes directrices (et le numéro des lignes directrices) se rapportant au sujet sont présentés ici. La concordance doit réduire la probabilité d'une omission au niveau des lignes directrices connexes.

Les directives énoncées dans le présent document ne présentent pas de solutions détaillées ou de spécifications exactes concernant la conception. L'élaboration de telles consignes gênerait plutôt la liberté de création de l'équipe de développement, en plus de représenter des difficultés du point de vue technique, d'être coûteuses en temps et de risquer de devenir désuètes au fil du temps. Le document présente plutôt des directives générales pour appuyer l'élaboration des concepts d'aide à la décision. Les solutions détaillées quant à la conception seront élaborées et évaluées par les équipes de développement à l'aide, entre autres, des critères d'évaluation énoncés dans le présent document. Dès que des solutions efficaces auront été établies, elles devront être saisies en tant que spécifications relatives à la conception et ajoutées aux directives fournies dans le présent document. En dernier lieu, chaque projet lié à l'élaboration d'aides à la décision pour le commandement et le contrôle de la Marine doit se reporter aux directives présentées dans le présent document ou, ultérieurement, au Guides de conception et d'évaluation tenant compte des facteurs humains - INCOMMANDS. Ainsi, tous les systèmes élaborés devraient être uniformes.

La vaste majorité des mesures d'évaluation décrites dans le présent document nécessitent une certaine forme d'expérimentation en matière d'intervention humaine. Cela est dû à une combinaison du manque de précision des concepts à mesurer (p. ex., la connaissance de la situation, la charge de travail et la confiance), du manque de précision des outils de mesure utilisés pour mesurer ces concepts et du manque de précision des lignes directrices elles-mêmes.

Il est donc impératif que toute leçon apprise dans le cadre d’un projet de développement d’IMO soit partagée avec l’ensemble de la collectivité.

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1 Introduction

The purpose of the INCOMMANDS TDP (Innovative Naval COMbat MANagement Decision Support Technology Demonstration Program) is to develop, demonstrate and evaluate advanced Above Water Warfare (AWW), Threat Evaluation and Weapons Allocation (TEWA) command decision support concepts (i.e., decision aids) for the command team of the Halifax Class Frigate in order to improve overall decision-making effectiveness. This work necessitates the design, development and evaluation of innovative Operator Machine Interface (OMI) concepts to support the operator's interaction with the command decision support concepts developed by the project team.

The intention of this document is to support the design and development of Operator Machine Interface (OMI) concepts developed as part of the INCOMMANDS TDP by providing a structured and comprehensive set of design guidelines which address decision aiding concepts specifically. The guidance within this document will be integrated within a final document, the INCOMMANDS Human Factors Design and Evaluation Guide, which will cover both OMI and decision aid guidance. This work was completed under contract to Defence Research and Development Canada (DRDC)-Toronto.

1.1 Background

1.1.1 Overview of the INCOMMANDS TDP

The INCOMMANDS TDP seeks to research, demonstrate and evaluate new command decision support concepts for the HALIFAX Class frigate's command and control (C^2) system with the objective of improving team battlespace awareness, and increasing decision speed and accuracy.

Advances in threat technology, the increasing difficulty and diversity of air, land, open-ocean and littoral scenarios, and the volume of data and information to be processed under time-critical conditions pose significant challenges to tactical C^2, in particular TEWA. The dynamic environment in which these activities are conducted is one of high risk and high stress as it includes organised, intelligent, lethal threats. It is also inherently uncertain due to the imprecise and incomplete nature of sensor data and intelligence, which places variable and unpredictable demands on decision makers. These and other factors are leading to increased demands for time-pressured decision making in highly ambiguous tactical situations. They are also contributing to a rapidly growing data overload problem for a ship's Command Team. These performance requirements necessitate that INCOMMANDS technologies enhance decision making under high-workload, high-stress and uncertain conditions. A central premise underlying the INCOMMANDS TDP is that Canadian warships will be required to have advanced and innovative C^2 decision aid capabilities that will improve operator decision-making effectiveness in the context of TEWA. The intention is that the decision aiding concepts will present information and provide decision recommendations in such a way as to reduce the mental demands placed on an operator.

Specific objectives of the INCOMMANDS TDP are to:

1. Develop and demonstrate advanced Above Water Warfare (AWW) command decision support concepts in a manner that will assist the Halifax Modernized Command and Control System (HMCCS) project define specifications for TEWA functions that are practicable for Canadian industry;
2. Elicit the Canadian Navy's cognitive/decision support and information requirements to perform single ship AWW command and control;
3. Develop a flexible and robust software architecture that enables the integration of heterogeneous algorithms and incremental enhancements;
4. Develop a knowledge-based framework that allows the efficient exploitation of *a priori* information and improves both human and automated TEWA functions;
5. Develop comprehensive evaluation methods and metrics (i.e., measures of performance and effectiveness) that permit the empirical validation and assessment of new decision making aids and human decision-making effectiveness;
6. Develop an advanced naval C^2 modeling and simulation capability that will be compatible with, and of interest to, the Canadian Forces Maritime Warfare Centre (CFMWC); and,
7. Explore multi-ship TEWA concepts in order to support the Canadian Navy's contribution to the international Battle Management Command, Control, Communications, Computers and Intelligence (BMC4I) project through a Task Group conceptual study.

1.1.2 INCOMMANDS OMI Development: The Role of Human Factors Guides

CAE Professional Services (Canada) has been contracted by Thales Canada to provide OMI design concepts for the decision support component of the INCOMMANDS TDP for DRDC Valcartier. This OMI development work is guided, in part, by a number of existing Standards (e.g., MIL-STD-1472, Section 5.14) and Style Guides that provide general guidance and recommendations on the 'look and feel' of an interface (e.g., layout, symbology, interaction methods). For example, the Command Decision Aiding Technology (COMDAT) TDP developed an OMI style guide that provided a common framework for new developments in command decision aids. The COMDAT OMI style guide comprises a discussion of identified Human Factors and usability issues within the specific command and control functions of a Halifax-Class Canadian Patrol Frigate (CPF).

1.1.3 Limitations of Existing Human Factors Guides

The COMDAT OMI Style Guide and most its antecedents, while reflecting current OMI knowledge and directed at Maritime C^2 System, focus primarily on the 'look and feel' of the interface and provide little guidance on the use and design of decision aids. Since most command and control systems under development are expected to contain considerable automation and decision support, it is important that existing Human Factors guidance on the use of decision aids be made readily available to OMI designers and developers.

Another limitation of style guides is that they rarely include guidance on how to evaluate an OMI to determine its compliance. Often, compliance is based on a heuristic evaluation of the proposed OMI by a Human Factors practitioner. While this may be sufficient for assessing specific, well-defined aspects of the display design, it is less satisfactory for assessing less prescriptive and more abstract guidance. Examples might include statements such as “the system shall maintain operator Situation Awareness” or “all colours shall be easily discriminated”. The addition of recommended methods for evaluating compliance makes a style guide more useful to project managers who call-up a style guide as part of a system specification.

1.2 INCOMMANDS Human Factors Design and Evaluation Guide

1.2.1 Objectives

The goal of the INCOMMANDS Human Factors Design and Evaluation Guide is to inform and guide the design and development of the OMI design concepts explored within the INCOMMANDS TDP. In order to achieve this goal, the objectives of the INCOMMANDS Human Factors Design and Evaluation Guide are as follows:

- To incorporate recommended standards and guidelines that will guide and inform the design of OMI and decision aiding concepts developed within the INCOMMANDS project so that they are consistent with Human Factors best-practice;
- To provide common OMI design guidance for existing decision aids, decision aids under development, and future decision aiding concepts, within the context of Maritime C^2, including Threat Evaluation and Weapons Assessment (TEWA); and,
- To provide general guidance, in terms of suggested metrics and tools, for the evaluation of a proposed OMI’s compliance with the guidelines within the style guide.

To meet these objectives, the INCOMMANDS Human Factors Design and Evaluation Guide will utilise material from the following documents:

- The COMDAT OMI Style Guide, which provides general guidance on the design of the OMI. The OMI guidance from the COMDAT OMI Style Guide will be revised to reflect the requirements of the INCOMMANDS OMI; and,
- The current document, which provides guidance on the design of decision aiding concepts specifically.

1.2.2 Terminology

Given the propensity of computer-based systems that assist the operator in a myriad of mental and physical activities (e.g., decision making aids, decision aids, automation, adaptive automation, intelligent automation, intelligent adaptive interfaces, expert systems, knowledge-based systems, data fusion, and information fusion) to varying degrees of autonomy (e.g., tool, aid, associate, autonomous agent) and sophistication (e.g., assistant, associate or coach), the generic term *Electronic Support System (ESS)* has been used in this report to refer to all of the systems, and similar, that are cited above. The terminology used in this document is as follows:

Electronic Support System (ESS): A sophisticated computer-based system, which embodies domain expertise, used to assist decision makers in:

- Acquiring, fusing, modelling and displaying information;
- Aiding the decision maker in evaluating and integrating information;
- Presenting a synthesized picture of the situation;
- Making decisions; and,
- Implementing a course of action.

Operator: The human who uses the ESS to assist in the successful completion of their task(s).

All of the design guidelines within this document are written as recommendations (i.e., *shall)*. The intent of the language is not to imply that all guidance pertaining to the design of the ESS presented in this document is required. Rather, the intent is that the OMI and ESS design follow the recommendations presented herein where possible. Much of the guidance within this document was developed for the aviation domain and, as such, its applicability to the naval C^2 domain must be carefully considered before implementation. Once again, the implementation of the advice must be carefully considered and evaluated using the evaluation criteria suggested.

1.3 Scope of Document

The guidance within this document does not present detailed design solutions or exact specifications. As well as proving to be technically difficult, time consuming and prone to obsolescence over time, to do so would inhibit the creative scope of the development team. Instead, this document presents generic guidance to support the development of decision aiding concepts. The detailed design solutions will be developed and evaluated by the development teams using, in part, the evaluation criteria provided in this document. As successful solutions are developed, they should be captured as design specifications and added to the guidance provided in this document. Finally, each project related to the development of decision aids for Maritime C^2 should refer to the guidance presented in this document, or eventually to the INCOMMANDS Human Factors Design and Evaluation Guide. In doing so, consistency across all systems that are being developed should be achieved.

This document includes the following sections:

a. Introduction;

b. Design Guidelines (including guidance for evaluating compliance); and,

c. Conclusions and Next Steps.

1.4 Bibliography

The following references were used to formulate the guidance within this document. It is important to note that all the following documents cite many other references; however this document does not cite these secondary or tertiary references. Instead, the OMI developer is encouraged to read the source documents if further clarification or information is required.

1.4.1 Military Standards

DEF-STD-00-25 Human Factors for Designers of Equipment, 24 May, 1996.

MIL-STD 1472F Department of Defense Design Criteria Standard – Human Engineering, 23/08/99. (Supersedes MIL-STD 1472 C, D, E).

1.4.2 Book Chapters

Endsley, M.D. (1996). Automation and Situation Awareness. In R. Parasuraman & M. Mouloua (Eds.). *Automation and human performance: Theory and applications* (pp. 163-181).Mahwah, N.J. Lawrence Erlbaum.

> This chapter discusses how various factors – monitoring, passive decision making, poor feedback and poor mental models – can impact Situation Awareness and out-of-the-loop performance problems when interacting with automated systems. Endsley introduces some guidelines for the design and evaluation of automated systems to minimize these problems and thus allowing the potential benefits of automation to be realized.

Zachary, W. W. and Ryder, J. M. (1997). Decision Support Systems: Integrating decision aiding and decision training, In M. G. Helander, T. K. Landauer, and P. V. Prabhu (Eds.). *Handbook of Human-Computer Interaction*, pp 1235-1258. Amsterdam, The Netherlands: Elsevier Science.

> The authors argue that experts, novices, and intermediate-level individuals vary not (just) in the amount of knowledge but in the organization and representation of that knowledge. For experts, there is typically a high degree of commonality imposed by the domain itself and by sociology of knowledge in the operational community, whereas novices and intermediate-level individuals have less coherent knowledge structures and exhibit more variability in knowledge content and strategies. Decision aids should therefore be tailored to the expertise and skill of the decision maker. In addition, the support given to operators of one level of expertise should not interfere with the support given to operators of other levels of expertise.

1.4.3 Technical Reports

Ahlstrom, V., and Longo, K. (2003). *Human factors design standard [HFDS 2003]. (Report number* DOT/FAA/CT-03/05 HF-STD-001*): Chapter 3 – Automation.* Atlantic City International Airport, NJ: DOT/FAA Technical Center.

> The Human Factors Design Standard (HFDS) provides reference information to assist in the selection, analysis, design, development, and evaluation of

new and modified Federal Aviation Administration (FAA) systems and equipment. This document is based largely on the 1996 Human Factors Design Guide (HFDG) produced by the FAA in 1996. It converts the original guidelines document to a standard and incorporates updated information, including the newly revised chapters on automation and human-computer interface. The updated document includes extensive reorganization of material based on user feedback on how the document has been used in the past. Additional information has been also been added to help the users better understand tradeoffs involved with specific design criteria. This standard covers a broad range of human factors topics that pertain to automation, maintenance, displays and printers, controls and visual indicators, alarms, alerts and voice output, input devices, workplace design, system security, safety, the environment, and anthropometry documentation. This document also includes extensive human-computer interface information.

Aviation Human-Computer Interface (AHCI) Style Guide. (1998). Report Number 64201-97U/61223. Prepared by Veridian, Veda Operations

The AHCI Style Guide presents guidelines to assist in the selection, analysis, design, development and evaluation of tri-service military aircraft cockpits, with emphasis on Army aviation. These guidelines are intended to complement and extend those published in other Department of Defense (DOD) HCI Style Guides.

DISA (1996). *Department of Defense Technical Architecture Framework for Information Management. Volume 8: DoD Human Computer Interface Style Guide* (Version 3.0). Washington, DC: Defense Information Systems Agency, Center for Information Management.

The Department of Defence (DoD) Human Computer Interface Style Guide provides reference information to assist in the selection, analysis, design, development, and evaluation of new and modified decision aid systems and equipment. This guideline covers a broad range of human factors topics that pertain to the design and implementation of decision aids. This document is largely based on User-Centered Design (UCD) principles.

1.4.4 Journal Articles

Endsley, M.R. and Kaber, D.B. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. *Ergonomics*, *42(3)*, 462-492.

This paper details a study performed to explore various levels of automation (LOA) designating the degree of human operator and computer control on overall human/ machine performance within the context of a dynamic control task. Thirty subjects performed simulation trials involving various levels of automation. Several automation failures occurred and out-of-the-loop performance decrements were assessed. Results suggest that, in terms of performance, human operators benefit most from automation of the implementation portion of the task, but only under normal operating conditions; in contrast, removal of the operator from task implementation is detrimental to performance recovery if the automated system fails. Joint human/system option generation significantly degraded performance in comparison to human or automated option generation alone. Lower operator workload and higher situation awareness were observed under automation of the decision making portion of the task (i.e., selection of options), although human/system performance was only slightly improved.

Parasuraman, R. and Riley, V. (1997). Humans and automation: Use, misuse, disuse and abuse. *Human Factors, 39*(2), 230-253.

This paper addresses theoretical, empirical and analytical studies pertaining to human use, misuse, disuse and abuse of automation. Understanding of these factors can lead to improved system design, effective training methods and policies and procedures involving automation use. Guidelines for the effective implementation of automation are presented.

Sheridan, T.B. (2000). Function allocation: algorithm, alchemy or apostasy? *International Journal of Human-Computer Studies, 52,* 203-216.

The paper discusses the following problems of allocation functions or tasks to the human or the system: (1) computers, automation and robotics offer ever greater capability, but at the cost of greater system complexity and designer bewilderment, making the stakes for function allocation ever higher than before; (2) proper function allocation differs by process stage; (3) automation appears most promising at intermediate complexity, but the bounds of “intermediate” are undefined; (4) “human-centered design”, while an appealing slogan, is fraught with inconsistencies in definition and generalizability; (5) “naturalistic decision-making” and “ecological” design are incompatible with normative decision theory; (6) function allocation is design, and therefore extends beyond science; and (7) living with the technological imperative, letting our evolving machines show us what they can do, acceding or resisting as the evidence becomes clear, appears inevitable.

1.4.5 Conference Proceedings

Hutchins, S.G., Morrison, J.G., and Kelly, R.T. (1999). Principles for aiding complex military decision making. In *Proceedings of the Second International Command and Control Research and Technology Symposium. Monterey, CA.*

Details the design and testing of a decision support system that was developed as part of the Tactical Decision Making Under Stress (TADMUS) program. The central hypothesis for the research is that presenting decision makers with decision support tools which were designed to parallel the cognitive strategies employed by experts, as observed in naturalistic settings, will reduce the number of decision making errors. Topics include a discussion of: (1) the theoretical background for the TADMUS program; (2) a description of the cognitive tasks performed; (3) the decision support and human- system interaction design principles incorporated to reduce the cognitive processing load on the decision maker; and (4) a brief description of the types of errors made by decision makers and interpretations of the cause of these errors based on the cognitive psychology literature**.**

1.5 Relationship to Other Documents

The following documents are directly relevant to this report.

1.5.1 INCOMMANDS Human Factors Engineering Program Plan (HFEPP)

The INCOMMANDS Human Factors Engineering Program Plan (HFEPP) (Baker, Banbury and McIntyre, 2006) outlines the approach for the Human Factors aspects of the INCOMMANDS project (i.e., analysis, OMI design, and verification).

1.5.2 INCOMMANDS Mission, Function and Task Analysis of TEWA Operations in Halifax-class Ships

The INCOMMANDS MFTA document (Baker, Banbury and McIntyre, 2006) describes the methodology and the results of the Mission, Function and Task Analysis (MFTA) that was conducted on the integration of the INCOMMANDS TEWA system into the HALIFAX Class ships. The intent of this report is to focus on the primary users Operations Room Officer (ORO) and Sensor Weapons Controller (SWC) of the INCOMMANDS system.

1.5.3 INCOMMANDS Operator Machine Interface Concepts

The INCOMMANDS Operator Machine Interface (OMI) document (Baker, Banbury and McIntyre, 2006) presents a concept of operations (CONOPS) as well as preliminary design concepts, and the associated rationale, for the INCOMMANDS decision support OMI. The intent is to document the OMI design sufficiently for Thales to be able to start the prototyping process, and to document traceability from the analysis results through to the OMI design.

1.5.4 INCOMMANDS Demonstration and Experimentation Plan (DEP)

The INCOMMANDS DEP outlines the experimentation objectives and structured methodology that will be used to assess and demonstrate the impact of a prototype Command Decision Support Concept (CDSC) capability on the performance of Threat Evaluation and Weapons Assignment (TEWA) activities conducted on the Halifax Class Frigate.

1.5.5 Command Decision Aiding Technology (COMDAT) OMI Style Guide

The COMDAT OMI Style Guide Version 1.0, published in 2001, defines the overall ‘look and feel’ philosophy of the OMI screens and functions to support development of Command Decision Aids for Halifax-Class Canadian Patrol Frigates (CPFs). The COMDAT OMI Style Guide will be combined with the guidance pertaining to the design of decision aiding concepts within this document to create the

INCOMMANDS Human Factors Design and Evaluation Guide. The OMI guidance from the COMDAT OMI Style Guide will be revised to reflect the requirements of the INCOMMANDS OMI.

2 Electronic Support Systems

The following section describes the rationale for the structure of the guidance pertaining to the design of ESSs that support decision making. The large number and diversity of the guidelines relevant to the design of OMIs for ESSs presents a significant challenge to the development of an appropriate structure that facilitates rapid access by the reader to the relevant guidelines.

2.1 Definition

Electronic support systems are systems that provide support to human decision-making processes, either unsolicited or by operator request. Electronic Support Systems can narrow the decision alternatives down to a few plausible options or suggest a preferred decision based on the available data. Advanced computer-based ESSs and displays represent a promising means of supporting decision makers in complex, dynamic and uncertain environments. For example, they can help alleviate the high levels of cognitive and collaborative demands placed on operators working within these types of environment. Such technological solutions should also be instrumental in helping operators, both individually and as a team, respond in an increasingly agile, adaptive and effective manner in the face of growing complexity, novelty and change.

2.2 Limitations

Complex information gathering and processing systems have been designed to aid the decision-maker in the past. However, these systems often increase the decision-maker's burden due to the inherent system complexity and the failure to design them in a way that mitigate the cognitive processing limitations of the operator, or in a way that ensures compatibility between the system and the tasks conducted by the operator. Often, these systems require operators to perform difficult cognitive tasks under intense levels of workload. They must perceive, synthesize and determine the relevance of a continual stream of incoming information, often pertaining to several concurrent entities, while projecting future anticipated events and making decisions regarding actions to be taken. The result is that the decision makers may fail to remember or overlook critical pieces of information, lose awareness of the situation and make hurried decisions that produce flawed and ineffective courses of action. An effective ESS, therefore, should synthesize much of the information used to develop situation awareness and present a coherent picture of the situation to the operator by performing many of the cognitive processing tasks on behalf of the operator and presenting fused and integrated information to the operator (Hutchins, Morrison and Kelly, 1999).The design of an ESS OMI, and its related functionality, is therefore critical to support operator decision making. A set of guidelines for use as a reference during OMI design development should ensure that the system is able to support the decision making processes of the operator, as well as promoting high levels of operator trust and acceptance of the system. The guidance within this document therefore comprises guidelines relevant to aiding and supporting operator decision making in uncertain, novel, or time-critical environments.

2.3 Taxonomic Classification of ESS Technologies

In order to structure the guidelines within this document a conceptual framework based on the work of Neisser was used. Neisser (1976) formulated the concept of a ‘Perceptual Cycle’, whereby the interaction between the human and his or her environment shapes the human’s perceptions, decisions and actions (see Figure 1). In this view, cognition is a continuous cycle of perception, decision and action whereby these processes occur in parallel and with different foci. Each of these processes provides both cognitive limitations and unique human strengths. Similar frameworks can be found in the Observe Orient Decide Act (OODA) loop (Boyd, 1976), the Perceptual Control Theory (Powers, 1973) and models of Situation Awareness in dynamic decision making (Endsley, 1996).

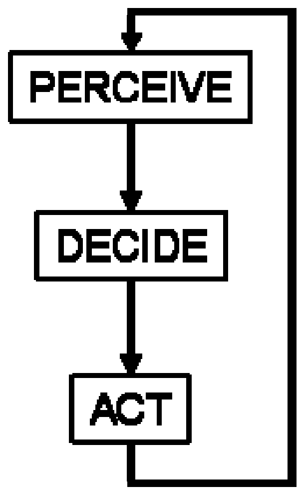

Figure 1: The Perceptual Cycle (Neisser, 1976).

The focus of the guidance within this document is to provide support to the development of tools to aid the operator make decisions, as well as to provide support to the development of tools that aid the operator acquire and manage information and instigate a course of action. For example, an effective decision aid should synthesize and present relevant information in such a way as to provide the operator with an accurate and coherent picture of the situation so that effective and timely decision can be made. In addition, the system should also assist the operator in performing the determined course of action.

The breadth of how computer-based systems can assist the operator in a myriad of mental and physical activities is reflected by the large variety of names given to these systems. As discussed in section 1.2.2 of this report, the generic term Electronic Support System (ESS) has been used in this report to refer to all of the systems, and similar, that are cited above. Furthermore, these systems can be classified within the Neisser’s perceptual cycle (see Table 1).

In line with the *Perceive-Decide-Act* structure, ESSs can be classified in terms of:

2.3.1 Information Management Aids (‘Perceive’)

Systems include information acquisition and integration (e.g., data and information fusion). This type of aiding includes filtering, distributing or transforming data, providing confidence estimates and integrity checks, and enabling Operator requests. Finally, Information Acquisition Aids might also manage how this information is presented to the Operator.

2.3.2 Decision Making Aids (‘Decide’)

These systems provide support to human decision making processes, either unsolicited or by operator request, by narrowing the decision alternatives down to a few plausible options, or by suggesting a preferred decision based on the available data.

2.3.3 Control and Action Aids (‘Act’)

These systems execute actions or control tasks with some degree of autonomy.

Table 1: The taxonomic classification of Electronic Support Systems (ESSs) in terms of their support to operator perception, decision making and/or action.

PERCEIVE	DECIDE	ACT
Data Fusion	Decision Support System (DSS)	Conventional Automation (e.g., autopilot)
Information Fusion	Decision Aid	Adaptive Automation
Intelligent Adaptive Interfaces	Knowledge-Based System (KBS)	
	Expert System	
	Intelligent Aiding	
	Associate Systems Technology	

3 Decision Aid Guidance

3.1 Guidance Structure

The structure of the guidance within this document follows the *Perceive-Decide-Act* classification of ESS technologies. The first section comprises guidance relating to ESS-specific OMI design guidelines (more general OMI guidance can be found in the COMDAT OMI Style Guide and in Annex A of this report). The next section is devoted to specific guidance relating to specific classes of decision aids; Information Management Aids (guidelines to optimise and organise the information presented for efficient information acquisition and synthesis), Decision Making Aids (guidelines to support efficient and effective decision making), and Control and Action Aids (guidelines to minimise operator out-of-the-loop problems). Finally, the last two sections of the Style Guide cover guidelines relating to Design and Evaluation, and Training and Implementation.

The structure is summarized below:

3.3 ESS OMI Design Guidelines

- 3.3.1 General Design Goals
    - 3.3.1.1 Employ Operator-Centered Principles
    - 3.3.1.2 Optimize Human-System Interaction
    - 3.3.1.3 Promote ESS Robustness and Resilience to Operator Error
    - 3.3.1.4 Support Operator Monitoring of ESS Functioning
- 3.3.2 Employ Operator-Centered OMI Design
- 3.3.3 Support Different Modes of Operation
- 3.3.4 Provide System Response and Feedback
- 3.3.5 Support Identification and Management of ESS Faults and Failures

3.4 Class-specific Guidelines

- 3.4.1 Information Management Aids
    - 3.4.1.1 Optimize Information Presentation and Information Management
    - 3.4.1.2 Optimize Display of Information
- 3.4.2 Decision Making Aids
    - 3.4.2.1 Ensure Appropriate Implementation
    - 3.4.2.2 Support Decision Making Strategies
    - 3.4.2.3 Keep Operators in Control
    - 3.4.2.4 Maximize Operator Situation Awareness by Increasing System Transparency
- 3.4.3 Control and Action Aids

3.1.1 Example of Guideline Format

The following section describes the format of each and every Human Factors guideline presented within the Style Guide. The intention was to impose a consistent and logical format on each guideline to assist the reader in finding the relevant guideline(s) quickly. The format is illustrated in Table 2, and the legend is described below:

Table 2: Example of Human Factors guidelines within the Style Guide.

1.1 ①	**Provide accurate and reliable information** ②	Source: HFDS, 2003 / Martel, 1996 ③	
Guideline(s): ④ 1. The ESS shall provide accurate and reliable information. That is, the correctness of the information in reflecting the reality.			
Discussion: ⑤ 1. Accurate and reliable information contributes to the Operator's trust in the ESS, supports the decision making process and increases the probability of an appropriate course of action being chosen.			
Evaluation Measures and Methodology: ⑥ System Performance:	Inspect	Demonstrate	Experiment
• Percentage of tracks correctly identified	☐	☑	☐
• Percentage of tracks correctly identified	☐	☑	☐
• Percentage of false alarms and misses	☐	☑	☐
• Age of information	☐	☑	☐
Relationship to Other Guidelines: ⑦ • If accurate and reliable information can not be presented to the Operator, refer to Guideline 1.2.3			

① *Guideline Number*. A unique reference number given to each guideline, or set of guidelines, to enable rapid searching for a particular guideline.

② *Guideline Title*. A short title that summarizes the topic of the guideline(s).

③ *Source*. A reference for the source document(s) from which the guideline(s) was (were) taken from.

④ *Guideline(s)*. A list of guidelines relevant to the topic. These are worded as 'shall' (i.e., mandatory) statements.

⑤ *Discussion*. Where relevant, supporting evidence for, and/or further discussion of, each guideline is presented in this section.

⑥ *Evaluation Measures and Methodology.* Evaluation measures and methodology are provided to determine compliance with the guideline(s). Evaluation measures relate to *System Performance*, *Task Performance*, *Operator Decision Quality*, *Operator Situation Awareness*, *Operator Workload*, *Operator Acceptance and Trust*, and *Operator Perceptions of Usabilty and Utility*. These measures are described in section 3.2. The exact criteria to which the components of the OMI are evaluated against (e.g., the extent to which the OMI affords adequate Situation Awareness or workload 'levels') should be determined on a case-by-case basis; as such, it is beyond the scope this document to provide exact values, or thresholds, to each and every evaluation criteria mentioned. The evaluation measures described in the next section can be administered by the following methodologies: *Inspection* (e.g., a visual inspection to determine that menu structure is compliant with guidelines, or visual measurement of font size to determine compliance); *Demonstration* (e.g., a walk-through by a Human Factors professional, to determine that uncertainty information regarding system advice is compliant with guidelines); and *Experimentation* (e.g., modeling or simulation activities, or a human-in-the-loop experimental or questionnaire-based study to determine that the system promotes acceptable levels of operator workload).

⑦ *Relationship to Other Guidelines*. Relevant guidelines (and the Guideline Number) to the topic are presented here. Cross-referencing should make it less likely that related guidelines are overlooked.

3.2 Evaluation Measures

The following system-based and operator-based measures of effectiveness were derived from, in part, the INCOMMANDS Demonstration and Experimental Plan (DEP).

3.2.1 System-based Measures of Effectiveness

The following measures of system-level effectiveness are illustrative of system-level (i.e., human-machine) measures of effectiveness:

- Time to detect targets, taken from the time the target was available for detection by the system's sensors to the time of actual threat determination;

- Percentage of targets detected, through a comparison of system-determined targets versus ground truth in any experimental situation;
- Percentage of targets recognized/identified, through a comparison of the identification of detected targets versus ground truth in any experimental situation; and,
- Accuracy of target location of all target detection/recognition/identification, through a comparison of reported positions versus ground truth.

3.2.2 Operator-based Measures of Effectiveness

The following measures of operator performance were derived form the INCOMMANDS Mission, Function and Task Analysis of TEWA Operations in Halifax-class Ships and are described in more detail within the INCOMMANDS Demonstration and Experimentation Plan (DEP).

3.2.2.1 Operator Performance

3.2.2.1.1 Speed of Task Completion

Measurement of Task Performance Speed can be used to provide an objective measure of operator performance for pre-defined sequences of events (e.g., time taken to detect target, time taken to identify target, time taken to apply combat power). Determination of task performance speed can be measured manually by means of a stopwatch during real time or later by means of video analysis. Task performance speed can also be determined automatically by means of time a marker in the prototype evaluation software which determines the time increment between predefined task start and stop times.

3.2.2.1.2 Accuracy of Task Performance

Measurement of Task Performance Accuracy can be used to provide an objective measure of operator performance of pre-defined sequences of events (e.g., correct target identification, correct application of combat power). Determination of task performance accuracy can be measured by comparing test participant performance and output against pre-determined performance criteria.

3.2.2.2 Operator Decision Making Quality

One difficulty with conducting research on operator decision making is deciding how ‘performance’ is defined. For example, the notion of what constitutes a ‘correct’ decision is highly subjective and context-dependent. Research to-date has been dominated by assessing the quality of a decision by quantifying the value of the outcome for a given event. In many instances this will be a binary output in terms of a simple ‘correct’ or ‘incorrect’ outcome. Unfortunately, such a measure reveals little of the decision processes involved in arriving at a course of action; indeed, a correct decision could have been reached by guess-work alone (see Clark, Banbury, Richards and Dickson, 2004, for a discussion).

3.2.2.2.1 Situation Assessment: Decision ‘Substrate’

It is important to consider decision making in the context of ‘process’ (i.e., how a decision was reached), rather than ‘outcome’ (i.e., what decision was reached). Inherent in the ‘recognition-primed’ accounts of decision making is the notion of pattern-matching the mental representation of the situation with past experience. Clearly, the quality of decision making is directly related to the quality of this mental representation of the situation, which in turn is directly related to the quality of the processes undertaken to acquire it. Thus, one way of assessing decision quality is to assess the quality of the situation assessment processes underlying the formation of the decision (i.e., the decision 'substrate'; see Clark, Banbury, Richards and Dickson, 2004).

For example, Banbury, Dudfield, Hoermann and Soll, (in press) developed a questionnaire-based measure to assess the efficacy of the situation assessment processes. The Factors Affecting Situation Awareness (FASA) questionnaire comprises 30 questions, divided into the following five sub-scales: Attention Management (participants' ability to attend to more than one task at a time and resume a task successfully after being interrupted); Information Management (participants' motivation to acquire appropriate information to make rational decisions); Cognitive Efficiency (participants' ability to ignore distractions and maintain SA despite external stressors); Automaticity (participants' experience of performing routine tasks in a highly practiced, automatic way), and Inter-Personal Dynamics (participants' knowledge of non-verbal communication and their views on what team membership entails). The FASA questionnaire was used in the assessment of a bespoke SA training program for commercial airline pilots by providing a more diagnostic measure of aircrews' acquisition and maintenance of SA.

3.2.2.2.2 Timeliness and Agility

With the nature of modern warfare relying heavily on information quality and supremacy, it has become crucial that operators are able to quickly adapt to the changing context within which they may find themselves. The speed of decision making can be couched in terms of decision 'timeliness' (e.g., a change of strategy at the appropriate time) and decision 'agility' (e.g., the ability to be adaptable to changing circumstances).

3.2.2.2.3 Consistency

The consistency of decision making is a useful insight into decision making quality, as it can be argued that differences of outcome from decisions based on the same data could indicate inappropriate or incorrect reasoning processes. Arguably, operators who have made accurate situation assessments and correct inferences based on these data, should reach the same outcome each and every time a similar decision is made.

Banbury, Selcon, Endsley, Gorton and Tatlock (1998), investigated how pilot decision making is affected by the manner in which Combat identification decision aid information regarding system reliability is presented, by requiring aircrew participants to respond to a machine-identified target with a "shoot/no shoot" decision. The study investigated whether the provision of an alternate option to the primary identification would affect the decision to shoot, especially if this secondary option was either another enemy aircraft or a friendly fighter. In addition, two different representations were evaluated; one in which the information was presented as system uncertainty; and the other in which it was presented as system confidence. The results indicated that decision making behaviour changed when the system explicitly identified a friendly aircraft as the secondary target – prior willingness to fire on a target with a relatively high level of uncertainty disappeared. The time taken to make the decision was also found to be mediated by what information was given. The use of consistency as a measure of decision quality therefore has some merit; participants were not able to reach the same decision to shoot, even though they were given the same information, albeit presented in different ways.

3.2.2.2.4 Justifiability and Rationality

Both justifiability and rationality serve to compliment the accuracy measure of decision making quality in that they provide further insight into the underlying processes that led the operator to make a decision. Specifically, operators that make an "inaccurate" decision may be able to fully justify their choice by providing the rationale behind their decision. The quality of this decision is therefore good, despite its seemingly inaccurate nature. Further, an "accurate" decision is not necessarily a good one given that it could have been made by chance alone (i.e., the operator guessed right). If the operator was asked why they made this decision, they would not be able to justify it or provide a corresponding rationale. In this case then, accuracy alone would provide an incomplete and misleading metric of the quality of the decision that was made.

3.2.2.3 Operator Situation Awareness

Situation Awareness (SA) is a key determinant of task performance and relates to the ability of the operator to maintain awareness of task-relevant objects in their immediate environment. The measurement of SA within the context of the INCOMMANDS TD project is important given the importance placed on automation-based technologies. On one hand, these technologies might afford the operator more information than they might otherwise have access to resulting in higher levels of operator SA. On the other hand, it is possible that too much reliance on these automation technologies might have a negative impact of operator's SA because the operator is consigned to monitoring the automation, and not fully engaged in the task.

3.2.2.3.1 Situation Awareness Global Assessment Technique (SAGAT)

SAGT is an objective measure of Situation Awareness. SAGAT employs periodic, randomly timed freezes in a simulation scenario during which all of the operators displays are temporarily blanked. At the time of the freeze a series of queries are provide to the operator to assess his or her knowledge of what was happening at the time of the freeze. The queries typically cover SA elements on all three levels of SA:

- Perception (i.e., noticing all of the relevant entities in the environment);
- Comprehension (i.e., understanding their meaning); and,
- Projection (i.e., anticipating their future states).

Queries are determined based on an in-depth cognitive tasks analysis that must be conducted for each domain SAGAT is used in. The questions are typically a random subset of a larger standard set of questions that are relevant to the training scenario. Operator's responses to these queries are scored based on what was actually happening in the simulation at the time of each freeze.

The main advantage of SAGAT is that it allows an objective unbiased index of SA that assesses operator SA across a wide range of elements that are important for SA in a particular system. The main disadvantage of SAGAT is that it requires freezes in the simulation, and as a result this measure can only be used for the laboratory evaluations. Because the freezes are random and over such a broad spectrum of operator SA requirements, operators cannot prepare for the queries and it has been found that the freezes do not affect performance in the simulations.

An alternative SAGAT approach is to measure the amount of time it takes a subject to report anomalies embedded into the scenario, then note the time it takes to deviate from the original plan, given the change in circumstances.

SAGAT can provide unique insight into crew performance within simulated team environments as well as individual performance. Queries can be designed to assess specific SA requirements for each team member role. More importantly, however, responses to queries related to common SA requirements can be compared across team members, identifying SA differences between team member roles. In addition, specific responses can be compared to determine whether the same responses (correct or incorrect) are made across team member roles. This type of analysis can provide diagnostic information regarding the source of breakdowns in team SA. For example, common incorrect responses may be indicative of problems that affect the entire team in a similar way (such as poorly designed information display). Alternatively, a mix of correct and incorrect responses or different incorrect responses across team member roles may be indicative of breakdowns in team coordination.

3.2.2.3.2 Situation Awareness Rating Technique (SART)

The Situation Awareness Rating Technique (SART) provides a validated and practical subjective rating tool for the measurement of SA, based on personal construct dimensions associated with SA. The structure of the construct dimensions has been interpreted as comprising three related conceptual groups, which form the principal dimensions of SART, namely:

- Demand for Attentional Resources or **D** (complexity, variability, instability);
- Supply of Attentional Resources or **S** (arousal, concentration, division of attention, spare mental capacity);
- Understanding of the situation or **U** (information quality, information quantity, familiarity).

The most commonly-used version of SART is the 14-dimension version (see Figure 2). Instead of numeric Likert-scales, a graphical display of the rating scales is utilized, where the length of line from the left hand side of the scale to the participant’s mark (in millimetres) represents a respective rating score for one item. The possible range is between 0 (“low”) and 50 (“high”).

Scoring. Questions 1, 2, 3 and 4 are averaged to give a **D** score (Demand). Questions 5, 6, 7, 8 and 9 are averaged to give a **S** score (Supply). Questions 10, 11, 12 and 13 are averaged to give a **U** score (Understanding). Situation awareness in total (**T**) is then calculated by **U - (D - S)**. Finally, Question 14 gives the participant’s confidence in their ratings of the above.

1. Demand on Attentional Resources (capacity) How demanding were the tasks on your attentional resources? Were they excessively demanding (high) or minimally demanding (low)?	*low*	*high*
2. Instability of Session How changeable was the session (situation)? Was it highly unstable and likely to change suddenly (high), or was it very stable and straight forward (low)?	*low*	*high*
3. Complexity of Session How complicated was the session? Was it complex with many interrelated components (high) or was it simple and straightforward (low)?	*low*	*high*
4. Variability of Session How many variables were changing in the session? Were there a large number of factors varying (high) or were there very few variables changing (low)?	*low*	*high*
5. Supply of Attentional Resources (capacity) How much of your attentional resources were you supplying to the session? Were you making the greatest possible effort (high) or giving very little attention (low)?	*low*	*high*
6. Arousal How aroused were you in the session? Were you alert and ready for activity (high) or did you have a low degree of alertness (low)?	*low*	*high*
7. Concentration of Attention How much were you concentrating on the session? Were you bringing all your thoughts to bear (high) or was your attention elsewhere (low)?	*low*	*high*
8. Division of Attention How much was your attention divided in the session? Were you concentrating on many aspects of the situation (high) or focussed on only one (low)?	*low*	*high*
9. Spare Mental Capacity How much mental capacity did you have to spare in this session? Did you have sufficient to attend to many new variables (high) or nothing to spare at all (low?)	*low*	*high*
10. Understanding of Session How well did you understand the session? Did you understand almost everything (high) or virtually nothing (low)?	*low*	*high*
11. Information Quantity How much information did you gain from your environment (inside and outside the cockpit)? Did you receive and understand a great deal of knowledge (high) or very little (low)?	*low*	*high*
12. Information Quality How good was the information you had gained from your environment (inside and outside the cockpit)? Was the knowledge communicated very useful (high) or was it of very little use (low)?	*low*	*high*
13. Familiarity with Session How familiar were you with the session? Did you have a great deal of relevant experience (high) or was it a new session (low)?	*low*	*high*
14. Confidence in Ratings How confident are you of the ratings you have just made? Are you very confident (high), or not very confident (low)?	*low*	*high*

Figure 2: Situation Awareness Rating Technique Input Form

3.2.2.4 Operator Workload

Another key determinant of task performance is the workload experienced by the operator when engaging in the tasks, and can be conceptualised in terms of both physical and mental effort. The following section describes a well-validated measure of workload:

3.2.2.4.1 NASA Task-Load Index (NASA-TLX)

NASA-TLX is a subjective workload assessment tool that allows operators to perform subjective workload assessments on operator(s) working with various human-machine systems. NASA-TLX is a multi-dimensional rating procedure that derives an overall workload score based on a weighted average of ratings on six subscales (see Figure 3). These subscales include:

- Mental Demands;
- Physical Demands;
- Temporal Demands;
- Own Performance;
- Effort; and,

- Frustration.

The degree to which each of the six factors contribute to the workload of the specific task to be evaluated, from the operator's perspective, is determined by their responses to pair-wise comparisons among the six factors. Magnitude ratings on each subscale are obtained after each performance of a task or task segment. Ratings of factors deemed most important in creating the workload of a task are given more weight in computing the overall workload score, thereby enhancing the sensitivity of the scale.

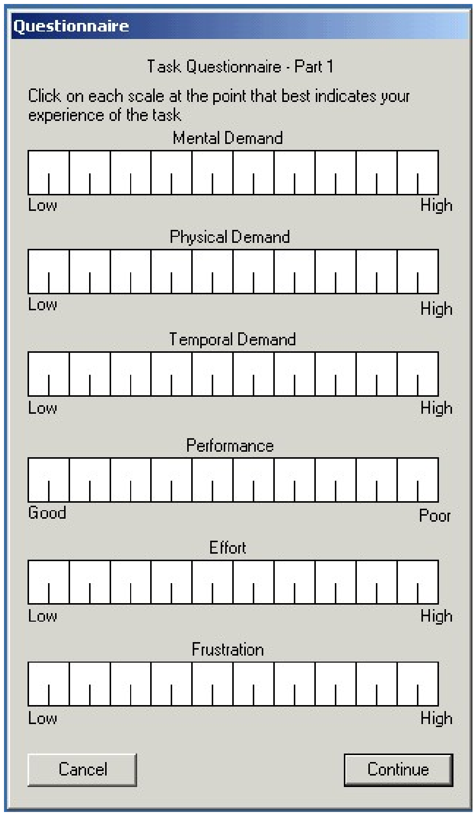

Figure 3: NASA TLX Dimensions and Scales

The simple nature of the scale permits subjects to provide ratings quickly in any operational settings. The scale can be administered using paper or via a direct operator input program, in real-time or administered retroactively, and it has been demonstrated that little information is lost when ratings are given retrospectively; a high correlation was found between ratings obtained "on-line" and those obtained retrospectively. The Task Load Index has been tested in a variety of experimental tasks that range from simulated flight to supervisory control simulations and laboratory tasks (e.g., the Sternberg memory task, choice reaction time, critical instability tracking, compensatory tracking, mental arithmetic, mental rotation, target acquisition, grammatical reasoning, etc.). NASA-TLX can be used to assess workload in various human-machine environments such as aircraft cockpits; C^2 workstations; supervisory and process control environments; simulations and laboratory tests.

3.2.2.5 Operator Fatigue

Operator performance, as well as general acceptance of the system, will be significantly affected by operational fatigue. It is therefore important to consider the effects of operator fatigue on the system in order to avoid negative outcomes due to fatigue-induced errors (e.g., when monitoring an automated system over extended periods of time).

The Fatigue rating questionnaire provides a simple subject self report measure of fatigue that can be administered at the same time as other system performance or acceptance measures (see Figure 4).

FATIGUE RATING (**Circle** the number of the statement which describes how you feel RIGHT NOW.)	
1	Fully Alert; Wide Awake; Extremely Peppy
2	Very Lively; Responsive; But Not at Peak
3	Okay; Somewhat Fresh
4	A Little Tired; Less Than Fresh
5	Moderately Tired; Let Down
6	Extremely Tired; Very Difficult to Concentrate
7	Completely Exhausted; Unable to Function Effectively; Ready to Drop
Comments:	

Figure 4: Fatigue Questionnaire

3.2.2.6 Operator Acceptance

The Technology Acceptance Model (TAM) is an information systems theory that models how operators come to accept and use a technology. The model suggests that when operators are presented with a system, a number of factors will influence their decision about how and when they will use it, notably:

- Perceived Usefulness (PU): This is defined as ‘the degree to which a person believes that using a particular system would enhance his or her job performance’.
- Perceived Ease-of-Use (PEOU): This is defined as ‘the degree to which a person believes that using a particular system would be free from effort.’

The TAM utilizes a questionnaire that has been assessed for robustness across populations and predictive validity. Studies have found high reliability and good test-retest reliability and have found that the instrument had predictive validity for intent to use, self-reported usage and attitude toward use. The sum of this research has confirmed the validity of the instrument, and supports its use with different populations of operators and different software choices.

3.2.2.6.1 Assessments of System Usability and Usefulness

A questionnaire relating to the high-level usability aspects of the OMI (e.g., suitability of screen windows, keyboard and joystick) is used to assess operator perceptions of system usability. Ratings are based on a five-point Likert scale; ranging from 1: Strongly Disagree to 5: Strongly agree. For example:

Statement	☹ Strongly Disagree	Disagree	Border	Agree	☺ Strongly Agree	Suggested Improvements
1. The size of the …. Window is suitable.	❑	❑	❑	❑	❑	

A questionnaire relating to the perceived utility of the workstation functions and capabilities (e.g., drill-down) is used to assess operator perceptions of system usefulness. Ratings are based on a five-point Likert scale; ranging from 1: Strongly Disagree to 5: Strongly agree. For example:

Statement ‘It is USEFUL to be able to…’	☹ Strongly Disagree	Disagree	Border	Agree	☺ Strongly Agree	Suggested Improvements
1. Drill-down to find out more information.	❑	❑	❑	❑	❑	

3.2.2.7 Operator Trust

Trust can be defined as the extent to which an operator is confident in and willing to act on the basis of the recommendations, actions, and decisions of an artificially intelligent decision aid. However, trust is not a simple uni-dimensional variable. It is possible to be correctly distrusting of a system (e.g., when it is unreliable), but also to be too trusting (‘over-trusting’ or complacent) or not trusting enough (‘under-trusting’ or sceptical).

Operator trust and acceptance of automation is determined from the outcome of a comparison process between the perceived reliability of the automated aid (i.e., trust in aid) and the perceived reliability of manual control (i.e., trust in self). Decision making quality will increase when the operator is able to compare the abilities of the decision aid with their own abilities. A subjective assessment can be used to measure the degree of operator trust in the decision aid. Overall trust in the decision aid is determined by cognition-based trust (i.e., trust relating to the operator’s perception of the automation) and affect-based trust (i.e., trust relating to the operator’s emotive response to automation). Three factors underpin cognition-based trust (i.e., perceived understandability, technical competence, and reliability [of the system]), and two factors underpin affect-based trust (i.e., faith [in the system] and personal attachment [to the system]). Each of these five factors has five sub-items as shown in Figure 5.

1. *Perceived reliability*

R1. The system always provides the advice I require to make my decision.
R2. The system performs reliably.
R3. The system responds the same way under the same conditions at different times.
R4. can rely on the system to function properly.
R5. The system analyzes problems consistently.

2. *Perceived technical competence*

T1. The system uses appropriate methods to reach decisions.
T2. The system has sound knowledge about this type of problem built into it.
T3. The advice the system produces is as good as that which a highly competent person could produce.
T4. The system correctly uses the information I enter.
T5. The system makes use of all the knowledge and information available to it to produce its solution to the problem.

3. *Perceived understandability*

U1. I know what will happen the next time I use the system because I understand how it behaves.
U2. I understand how the system will assist me with decisions I have to make.
U3. Although I may not know exactly how the system works, I know how to use it to make decisions about the problem.
U4. It is easy to follow what the system does.
U5. I recognize what I should do to get the advice I need from the system the next time I use it.

4. *Faith*

F1. I believe advice from the system even when I don't know for certain that it is correct.
F2. When I am uncertain about a decision I believe the system rather than myself.
F3. If I am not sure about a decision, I have faith that the system will provide the best solution.
F4. When the system gives unusual advice I am confident that the advice is correct.
F5. Even if I have no reason to expect the system will be able to solve a difficult problem, I still feel certain that it will.

5. *Personal attachment*

P1. I would feel a sense of loss if the system was unavailable and I could no longer use it.
P2. I feel a sense of attachment to using the system.
P3. I find the system suitable to my style of decision-making.
P4. I like using the system for decision-making.
P5. I have a personal preference for making decisions with the system.

Figure 5: Human-Computer Trust rating scale (Madsen and Gregor, 2000)

3.3 ESS OMI Design Guidelines

3.3.1 General Design Goals

3.3.1.1	**Employ Operator-Centered Principles**	Source: HFDS, 2003; Sheridan, 2000; DefStan, 1996, AHCI, 1998, DISA, 1996; MS1472F; Endsley and Kaber, 1999.

Guideline(s):

1. The ESS shall be used to support the operator(s) where appropriate (e.g., human-centered ESS), not implemented simply because the technology is available (e.g., technology-centered ESS).

2. The ESS shall be design to match the operator's mental model of the domain as well as the processes underlying system operation.

3. The ESS shall help or enable the operators to carry out their responsibilities and tasks

safely, efficiently, and effectively. [Carrying out a task effectively means producing the desired result. Carrying out a task efficiently means that the desired result is produced with a minimum of waste (usually in relation to time)]. 4. The operator shall always have final authority over the allocation of ESS functions (i.e., task allocated to human and/or system). 5. Functions shall be automated only to attain greater overall effectiveness, efficiency, reliability, simplicity, economy, and system safety without reducing human involvement, situation awareness, or human performance in carrying out the intended task. 6. The relationships between display, control, decision aid, and information structure and operator tasks and functions shall be clear to the operator.
Discussion: 2. The operator must interpret the information provided to him/her. The operator's training, experience, biases will influence the quality of the decision and execution of their task (s). 4. The reasoning behind this guideline is twofold. First, it is ultimately the operator who is responsible for the task. Second, ESS automation is subject to failure. Therefore, it is the operator, not the automation who must be in authority of the system with the automation playing a subservient role. 5. Automation can lead to distraction from the primary task, increased workload, boredom or complacency. 6. The operator needs to be able to see clearly how the display or decision aid, and so on, facilitates the completion of the necessary task

Evaluation Measures and Methodology:	Inspect	Demonstrate	Experiment
Design:			
• Analysis and design methodology compliant with MIL-HDBK-46855A (Human Engineering Program Process and Procedures)	☑	☐	☐
• Objective measures of the adequacy of OMI usability through usability testing	☐	☐	☑
Operator Acceptance:			
• Subjective assessment of the adequacy of system usability and utility (in terms of its design) using 'walk-through' or heuristic analysis[1] (e.g., Nielsen, 1994).	☐	☑	☐
• Questionnaire-based assessments of the adequacy of operator's perceptions of system	☐	☐	☑

[1] The criteria to make such a judgment will relate to all aspects of the OMI design. This would mean that most of the criteria within the rest of the document would need to have been met.

usability and utility			

Relationship to Other Guidelines:

- 3.3.1.2 Optimize Human-System Interaction
- 3.3.2. Employ Operator-centered OMI Design
- 3.4.2.3 Keep Operators in Control
- 3.5.1 Adopt Operator-Centered Design Principles

3.3.1.2	**Optimize Human-System Interaction**	Source: HFDS, 2003; DISA, 1996; Parasuraman and Riley, 1997; AHCI, 1998; MS1472F; Endsley, 1996; DefStan, 1996; Endsley and Kaber, 1999.

Guideline(s):

1. The ESS shall provide sufficient information to keep the operator informed of its operating mode, intent, function, and output; inform the operator of system failure or degradation; inform the operator if potentially unsafe modes are manually selected; do not interfere with manual task performance; and allow for manual override.
2. ESS system functioning shall be transparent to the operator at all times.
3. The operator shall have active involvement in the operation of the ESS. Operators shall be given an active role through relevant and meaningful tasks in the operation of a system, including when the tasks are automated.
4. ESS functionality shall be appropriate to the operator's level of expertise with the system (e.g., shortcuts such as function keys can be provided for the more experienced operators).
5. ESS functioning shall not increase the demands for cognitive resources (thinking or conscious mental processes).
6. Extreme levels of workload (low or high) due to ESS functioning shall be avoided (to maximize operator-in-the-loop and reduce automation bias).
7. Operator interaction with the ESS shall not require the operator to take significant amounts of attention away from the primary task.
8. ESS shall not interrupt at inappropriate times such as during periods of high workload or during critical moments in a process.
9. An ESS task shall be less difficult to carry out than the manual task it replaces.
10. Data that are needed by the operator shall be easily accessible.
11. The ESS shall allow the operator to interact directly with objects which are important to the

operator’s tasks.

Discussion:

2. The transparency of system functioning (i.e., the properties of the ESS which allow the operator to understand its actions) will increase the predictability of the ESS (e.g., reliability of automatically detecting and prioritizing tracks) by ensuring the operator is cognisant of the limitations of the ESS. In addition, it is very important that operators understand why, and under what conditions, the ESS might make errors. Trust should increase if operators receive informative feedback in the event of an ESS error (e.g., explanation of system error). For general information on providing feedback to the operator, see MIL-STD 1472F.

3. Operator awareness of ESS state can not be sustained passively. Active involvement is essential for operators to exercise their responsibilities and be able to respond to emergencies. Reducing active involvement may be detrimental to the operator’s understanding of important information, may lead to longer response times in case of emergencies, or, in the long term, may lead to loss of relevant knowledge or skills.

4. ESS functions that increase the demand for cognitive resources of the operator is an artefact of poor design. Expert operators in complex, dynamic systems have been observed to cope with poorly designed ESSs by using only a subset of the available functionality, especially during periods of high workload.

6. ESSs can cause extreme workload levels by increasing workload when it is already high and decreasing workloads that are already low. ESSs are often introduced to reduce workload. However, reduction of workload may not always be advantageous, for example, if workload is already low.

7. When an ESS requires the operator to devote a significant amount of attention to adjusting or monitoring the ESS functioning, this removes the operator away from minute-to-minute operations, thereby taking the operator out of the loop. This can be especially dangerous if an abnormal situation occurs that needs to be remedied quickly.

8. An interruption during high workload or at a critical moment can cause a delay in the operator’s ability to respond to an ESS malfunction, leading to a potential failure. If the operator is attending to an ESS malfunction and is interrupted, the interruption depletes the operator’s mental resources causing him to be less capable of averting the potential failure.

10. Operator requirements can serve as a guide to whether the data are available at all times, accessible at the operators’ discretion, or not at all if the operator does not need information.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Analysis and design methodology compliant with MIL-HDBK-46855A (Human Engineering Program Process and Procedures)	☑	☐	☐
• Objective measures of the adequacy of OMI ease of use and usefulness through Usability testing (e.g., observation-based studies)	☐	☐	☑

Operator Situation Awareness: • Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of ESS functioning.	☐	☐	☑
• Subjective (i.e., questionnaire) and objective (e.g., performance, errors) assessment of the adequacy of the operator's understanding of the limitations of the ESS.	☐	☐	☑
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of task-relevant objects in the environment.	☐	☐	☑
Operator Workload • Subjective assessment (i.e., questionnaire) of the adequacy of the operator's workload.	☐	☐	☑

Relationship to Other Guidelines:

- 3.3.1.1 Employ Operator-Centered Principles
- 3.4.2.4 Maximize Operator Situation Awareness by Increasing System Transparency
- 3.4.3.1 Keep Operators 'In-the-Loop'

3.3.1.3	**Promote ESS Robustness and Resilience to Operator Error**	Source: HFDS, 2003; MS1472F; DISA, 1996; Sheridan, 2000; AHCI, 1998; Parasuraman and Riley, 1997; DefStan, 1996.

Guideline(s):

1. The ESS shall be resistant to operator error while tolerating some reasonable level of "error" and response variability.
2. The ESS shall be able to monitor operator interactions and to warn of operator errors.
3. ESS functions shall be capable of being overridden by the operator in an emergency. ESS functioning shall not be difficult or time consuming to turn on or off.
4. Operators shall not be too reliant on ESS functioning to the extent that their skills are degraded by extended use of the ESS and that they can no longer safely recover from emergencies or operate the ESS manually if the ESS fails.
5. ESS shall not be able to veto operator actions leaving the operator without means to override or violate the rules that govern the ESS unless there is not enough time for the operator to make a decision.

6. ESS interactivity (i.e., navigation, functionality, features, information structure) shall be consistent within and between systems.

7. ESS status during system setup shall be transparent to the operator (e.g., system failure due to system setup or manual input of information).

8. Allocation of tasks shall be flexible and adaptable (e.g., a task allocated to an ESS or an operator can be adapted according to the context) and the operator shall always have authority over how the tasks are allocated.

9. The ESS shall make it clear whether the operator or the ESS is supposed to perform a particular task at a specific time.

10. The allocation of tasks related to decision/action to the ESS shall be under the authority of the operator; particularly under situations of greater uncertainty and risk.

11. To increase operator trust in the ESS, ESS performance shall be: reliable and predictable with minimal errors; robust (able to perform under a variety of circumstances); familiar (use terms and procedures familiar to the operator); and, useful.

12. The ESS shall be available to the operator as needed.

13. The ESS shall not interfere with task performance.

14. The ESS shall provide accurate and reliable information.

Discussion:

1. To make a system error resistant is to make it difficult for an operator to make an error. Simplicity in design and the provision of clear information are tools to improve error resistance. Electronic checklists also have the potential to improve error resistance by providing reminders of items that need to be completed. Error tolerance is the ability to mitigate the effects of human errors that are committed. Error tolerance can be improved by adding monitoring capabilities to the ESS. Acceptable levels of error and response variability enhance learning (of the operator).

4. A balance is needed between the efficiency created by the ESS, and the need for the operator to be able to recover from emergencies and control the ESS manually in case the ESS fails.

5. The resumption of manual control needs to be within the capacity of the operator, without relying on manual skills.

6. There are many possible types of interaction, such as menu selection, direct manipulation, and form-filling. An example of inconsistent interaction would be having one ESS require filling in forms as the interaction method, whereas another ESS requires menu-driven interaction. However, in the case of repetitive movement using a single input device (e.g., track-ball), operator fatigue can be mitigated by using an alternative method of interaction (e.g., touch screen in addition to the track-ball).

7. ESS failures are often due to setup error. Although the ESS itself could check some of the setup, independent error-checking equipment or procedures may be needed. The operator needs to be able to distinguish whether a failure occurred due to the ESS setup or due to an inaccuracy in the input information. A failure could have been caused by a malfunction

of an algorithm or by the input of inaccurate data. ESS operations that are easily interpretable or understandable by the operator can facilitate the detection of improper operation and the diagnosis of malfunctions. 8. Problems with an ESS can occur when ESS-generated options do not apply to a situation and the operator is restricted to the options provided by the ESS. 10. High levels of ESS automation (i.e., the ESS initiates and performs the task) can be used for tasks involving relatively little uncertainty and risk. Since the decision as to whether or not a situation is one of greater uncertainty and risk will be made by the operator, allocation should always be under control of the operator. 11. Trust in automation tends to be relatively stable. However, changes in trust may occur over time. Operator trust in automation can increase with reliable and predictable performance. Decreases in trust may occur as a result of some critical error or automation failure. It is more difficult for operators to regain trust in automation after a failure than to develop an initial trust. Higher trust in automation is not always better because automation errors may be overlooked due to complacency. Decreases in trust typically occur suddenly, but increases happen slowly and steadily. The consequences of an automation failure (for example, the magnitude of an error) impact the decline in trust. 13. An operator will be less likely to accept an automated system that interferes with their ability to perform tasks. 14. When operators believe the system to be highly reliable, they place greater trust in it. However, there is a trade-off involved with a constant high level of automation reliability and predictability. Constant high levels of reliability and predictability may be more likely to promote complacency and may cause operators to monitor the system with less vigilance.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Assess analysis and design methodology compliant with MIL-HDBK-46855A (Human Engineering Program Process and Procedures)	☑	☐	☐
• Objective measures of the adequacy of OMI ease of use and usefulness through Usability testing (e.g., observation-based studies)	☐	☐	☑
System Performance:			
• Predictability of the system	☐	☑	☐
Operator Performance:			
• Periodic objective assessment of operator skill-fade (e.g., assess competence to perform task manually) by a Human Factors practitioner. For example, at recurrent training intervals.	☐	☐	☑
Operator Situation Awareness:			
• Subjective assessment (i.e., questionnaire) of	☐	☐	☑

the adequacy of the operator's Situation Awareness of system functioning.			
• Subjective (i.e., questionnaire) and objective (e.g., performance errors) assessment of the adequacy of the operator's understanding of the limitations of the system.	☐	☐	☑
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of task-relevant objects in the environment.	☐	☐	☑

Relationship to Other Guidelines:

- 3.3.4 Provide System Response and Feedback
- 3.3.5 Support Identification and Management of ESS Faults and Failures
- 3.4.3.1 Keep Operators in Control
- 3.4.2.4 Maximize Operator Situation Awareness by Increasing System Transparency

3.3.1.4	**Support Operator Monitoring of ESS Functioning**	Source: HFDS, 2003; Parasuraman and Riley, 1997; Sheridan, 2000; Endsley and Kaber, 1997.

Guideline(s):

1. Informative feedback shall be given in case of an ESS failure; such as the likely cause and/or location of the failure.
2. The ESS shall be designed so that operators are able to monitor the ESS and the functionality of its hardware and software, including the display of status and trend information, as needed.
3. ESS tasks shall be designed so that operators are involved in active control and monitoring rather than just passive monitors.
4. System designers shall allow adequate cognitive resources for monitoring of the ESS by ensuring that task load does not become excessive.
5. Operators shall not be required to perform purely monitoring tasks for longer than 20 minutes at a time.
6. Important events shall occur in the same location on a display in order to promote effective monitoring performance, including when operators must monitor multiple displays.
7. The ESS shall provide some type of indication the system is still being monitored by some automatic system.

8. Critical ESS functions shall be independently monitored by the operator. A critical function is a function that can cause system failure when a malfunction is not attended to immediately.

9. Operators shall be given an adequate understanding (mental model) of how the ESS works in order to monitor effectively.

10. Intermittent periods of task monitoring by the operator shall be used during extended periods of task automation to improve monitoring of the ESS.

11. The effects on vigilance due to the use of ESS shall be considered before automating tasks or functions.

12. The ESS shall behave predictably so that the operator knows the purpose of the ESS functioning and how the task will be affected by that functioning.

13. The ESS shall provide means to indicate to the operator that data are missing, incomplete, unreliable, or invalid or that the system is relying on backup data.

Discussion:

1. Different messages shall be given, depending on whether the error is due to the central system or whether the error is local.

2. One way that this can be accomplished is by providing the operator with access to raw data that the ESS processes.

3. Failures in ESS functioning may be easier to detect when operators are involved in both active control and monitoring, than when they are just passive monitors.

4. Operators using ESS may experience higher levels of mental workload than manual controllers due to monitoring, diagnosis, and planning, with significant cognitive demand resulting from relatively “simple” vigilance tasks.

5. Operators may become complacent in monitoring an ESS if they have other tasks to complete simultaneously. Such decrements in operator monitoring of an ESS have been observed to occur in the laboratory in as little as 20 minutes.

6. Operators will be able to detect a particular event more easily if they know where that event will occur (i.e., spatial certainty). Spatial uncertainty has been shown to increase perceived workload and decrease performance efficiency. If operators do not know where on a display an event will occur then they must engage in visual scanning to look for the event.

8. When a function is critical, combining the monitoring of that critical function with other, possibly less critical functions may lead to delays in response. When a critical function is independently monitored, an operator can respond to a malfunction very quickly (within one second). If an operator is attending to another task when there is a malfunction, there will be a delay in the operator’s response (several seconds). In this period of delayed response, the malfunction can cause the system to fail. For this reason, critical functions require constant attention. Critical ESS functions do assist in the completion of critical tasks, however they do not assist in freeing the operator to attend to other tasks.

9. Operators must possess accurate mental models of the ESS in order to monitor effectively, comprehend current situations, plan their actions, predict future system states, remember past instructions, and diagnose system failures. One way to establish adequate mental models is through training.

10. Complacency is a major concern with the automation of tasks. If practicable (i.e., the operator is able to perform the task(s) manually), intermittent periods of manual control have been advocated as a means of minimizing complacency. Decrement of cognitive abilities such as Situation Awareness and the loss of manual skills may also occur, making transitions from automated to manual systems difficult. Because automation of tasks can decrease basic manual skills, these skills should be used and maintained, if practicable. Intermittent periods of manual control during which ESS functioning is suspended periodically can promote optimal operator performance, and allow better recovery from failure, regardless of the type of task that is automated.

11. A vigilance decrement, that is, a continuously decreasing ability to maintain attention over time while monitoring, may occur with the automation of tasks. Vigilance decrements do not occur because monitoring tasks are under-stimulating. Rather, they require a large amount of cognitive resources and are often frustrating. Vigilance decrements have been observed to occur for both expert and novice. How hard the operator must work in order to maintain vigilance can be determined by at least two factors. First, workload is affected by the ease with which relevant signals can be detected. Signals that have low salience are more difficult to detect than signals high in salience. Visual fatigue will also require more effort to be expended in order to detect a signal. Second, musculo-skeletal fatigue associated with maintaining a fixed posture will increase the workload needed to perform optimal monitoring.

12. The predictability of ESS functioning allows the operator to know what to expect when the ESS is functioning correctly. This makes it easier for the operator to recognize when the ESS is not functioning.

<u>Evaluation Measures and Methodologies:</u>	Inspect	Demonstrate	Experiment
Operator Performance:			
• Objective assessment of the adequacy of operator's accurate and timely detection of ESS faults and failures.	☐	☐	☑
Operator Situation Awareness:			
• Subjective assessment (i.e., questionnaire) of the adequacy of operator Situation Awareness of system functioning.	☐	☐	☑
Operator Workload:			
• Subjective assessment (i.e., questionnaire) of the adequacy of operator mental and physical workload.	☐	☐	☑
Operator Fatigue:	☐	☐	☑
• Subjective assessment (i.e., questionnaire) of			

the adequacy of operator fatigue. Operator Trust: • Subjective assessment (i.e., questionnaire) of the adequacy of Operator trust	☐	☐	☑

Relationship to Other Guidelines:

- 3.3.1.1 Employ Operator-Centered Principles
- 3.3.4 Provide System Response and Feedback
- 3.4.2.4 Maximize Operator Situation Awareness by Increasing System Transparency
- 3.6.2 Train to Overcome 'Automation Biases'

3.3.2	**Employ Operator-centered OMI Design**	Source: HFDS, 2003; Nielsen, 1994; Hutchins et al, 1999; Zachary and Ryder, 1997; MS1472F; AHCI, 1998; DefStan, 1996.

Guideline(s):

1. The ESS and associated integrated information displays shall be intuitive, easy to understand, and easy to use.
2. The ESS shall be simple for the operators to learn.
3. Support the operator recognising objects, actions and options rather than relying on the operator's memory (recall).
4. The ESS interface shall represent the simplest design consistent with functions and tasks of the operator.
5. The ESS interface shall be consistent with the expectations and understandings of the operator and shall reflect an obvious logic based on operator task needs and capabilities.
6. Navigation aids (e.g., landmarks) shall make it easy for operators to know where they are in the data space.
7. The OMI layout shall be organized according to the human perceptual system to reduce the operator's workload (e.g., proximity, matching patterns, unity, continuity, balance principles).
8. Where possible, spatial representations of information shall be used instead of verbal or textual displays to reduce the amount of mental computation needed to perform tasks (particularly for spatial tasks).
9. Dynamic information (i.e., information that changes over time) shall be presented in real time and on demand to ensure accurate and timely decision-making.
10. The ESS shall be flexible enough to allow for different operator styles and responses

without imposing new tasks on operators or affecting overall system performance.

Discussion:

2. Simplicity for the operator is achieved by attaining compatibility between the design and human perceptual, physical, cognitive, and dynamic motor responsiveness capabilities.
3. Objects, actions, and options shall be visible to the operator at all times. The operator shall not have to remember information from one part of the dialogue to another. Instructions for use of the system shall be visible or easily retrievable whenever appropriate.
5. Consistency can be obtained by presenting information in predictable locations and keeping elements of screens such as headers, fields, and labels consistent in appearance and relative location throughout a system or application.
6. Navigational aids can be a visually or cognitively salient object whose location can be associated with the locations of other objects. Landmarks, for instance, help people form a mental model for an information space. Because people perceive other objects in relation to this point of reference, a landmark will organize a space when people are searching for information (navigation).
7. By applying human perceptual and memory characteristics to interface design, the amount of work an operator must exert in order to understand the information being presented can be reduced and allow the operator to focus on important information.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Assess overall OMI design is compliant with other relevant Human Factors standards) and usability ‘heuristics’.	☑	☐	☐
• Objective measures of the adequacy of OMI ease of use and usefulness through Usability testing (e.g., observation-based studies).	☐	☐	☑
• Subjective assessment (i.e., questionnaire) of the adequacy of system usability and utility by Human Factors professional using ‘walk-through’ or heuristic analysis.	☐	☑	☐
Operator Acceptance:			
• Questionnaire-based assessment of the adequacy of the operator’s perceptions of system usability and utility	☐	☐	☑

Relationship to Other Guidelines:

- 3.3.1.1 Employ Operator-Centered Principles
- 3.3.2 Employ Operator-centered OMI Design

- 3.5.1 Adopt Operator-Centered Design Principles

3.3.3	**Support Different Modes of Operation**	Source: HFDS, 2003; Nielsen, 1994; MS1472F; DefStan, 1996.

Guideline(s):

1. Modes shall be used in complex ESSs to partition the possible operator actions so that not all tasks/actions are available at the same time. Modes shall be used where the operator is likely to remain in a system mode for a period of at least some minutes.

2. When control, display, or automation functions change in different modes of ESS operation, mode and function identification and status shall be clear and distinct to the operator by providing feedback and clear status indicators (e.g., sound effects or visual indication).

3. Seldom-used ESS modes and functions shall be clearly identified. As ESSs become more complex with many modes and functions, the cognitive burden caused by the need for mode awareness increases. Seldom-used ESS modes and functions will pose the largest burden on the operator because of a lack of familiarity. Enabling the operator to immediately recognize the purpose of ESS modes and functions can lessen this burden.

4. Frequently used ESS modes shall be more accessible than infrequently used ESS modes.

5. The number of different modes for a given ESS shall be minimized.

6. The operator shall be able to easily switch between ESS modes.

7. The ESS shall alert the operator to the implications of interactions between modes, especially when they are potentially hazardous.

8. The ESS shall either prevent the use of potentially unsafe modes or alert the operator that a particular mode may be hazardous.

Discussion:

1. Modes can be a frequent source of operator error because operators often mistake the current mode, often from a lack of effective feedback on the state of the ESS (including which mode is active). For example, a flight management system might include modes relating to the cruise and descent phases of the flight. In this case, the same cockpit controls are used to manipulate different flight variables (e.g., speed versus descent rate) according to which mode the pilot has selected. If it is not clear to the pilot which mode the automation is in, potentially dangerous flight parameters could be inputted inadvertently into the system.
2. Related systems shall have identical coding strategies, identical access and execution of system commands, consistent data display formatting, and consistent monitoring and reporting of resources.
5. Multiple modes will provide a means of flexibility but will introduce more opportunities for error. Furthermore, a system that has multiple modes of operation can be difficult to learn and can produce increases in workload.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Operator Situation Awareness: • Subjective assessment (i.e., questionnaire) of the adequacy of operator's Situation Awareness of system functioning in particular mode status (i.e., 'mode awareness').	☐	☐	☑
Operator Workload • Subjective assessment (i.e., questionnaire) of the adequacy of the operator's workload.	☐	☐	☑
Relationship to Other Guidelines: None			

3.3.4	**Provide System Response and Feedback**	Source: HFDS, 2003; DefStan, 1996; Parasuraman and Riley, 1999; MS1472F; DISA, 1996; Endsley, 1996.

Guideline(s):

1. The ESS shall continuously inform the operator about what it is doing, the purpose for doing so and how it is interpreting the operator's input. For every operator action, there shall be some feedback from the ESS. For frequent and minor actions, the response can be modest while for infrequent and major actions, the response shall be more substantial.
2. Feedback messages shall be phrased in a clear and precise manner and the use of abbreviations, and reference system shall be avoided.
3. The ESS shall provide a positive feedback to the operator regarding the acceptance or rejection of a data entry. When fixed-function key activation does not result in an immediately observable response from the ESS, the operator shall be given an indication of ESS acknowledgment.
4. The ESS shall keep the operator aware on a continuing basis of the function (or malfunction) of each automated sub-system and the results of that function (or malfunction). It is important to keep the operator 'in-the-loop' (i.e., provide sufficient transparency of the system for the operator to maintain adequate awareness of the system's functioning).
5. The ESS shall alert the operator when a problem or situation is beyond its capability.
6. The ESS shall alert the operator to any new/important developments occurring in the processing and predicting of outcomes and models.
7. Response times shall be as fast as possible. Normally, no special feedback is necessary during delays of more than .01 second but less than 1.0 second. For delays between 2 and 10 seconds, a "busy" indicator shall be given to indicate how much computer processing has been done. For delays longer than 10 seconds, percent-done progress feedback is to be given to indicate when the computer expects to be done (e.g., percent-done indicator).

Discussion: 4. When feedback is poor, ESS functioning is considered ‘silent’. Silent automation may result in coordination and system failures. Operators may be surprised by the behaviour of silent automation.			
Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design: • Assess compliance with relevant standards and usability ‘heuristics’ concerning system feedback (e.g., system response latencies).	☑	☐	☐
Operator Situation Awareness: • Subjective assessment (i.e., questionnaire) of the adequacy of the operator’s Situation Awareness of ESS functioning.	☐	☐	☑
Operator Performance: • Objective assessment of the adequacy of the operator’s accurate and timely detection of ESS faults and failures.	☐	☐	☑
Relationship to Other Guidelines: • 3.3.1.4 Support operator monitoring of ESS functioning • 3.4.2.4 Maximize Operator Situation Awareness by Increasing System Transparency			

3.3.5	**Support Identification and Management of ESS Faults and Failures**	Source: HFDS, 2003; DefStan, 1996; MS1472F; Parasuraman and Riley, 1997.

Guideline(s):

1. Make ESS failures apparent by making failure unambiguously obvious to the operator
2. Provide adequate early warning notification of pending ESS failure or performance decrements to allow the operator to adjust to the new task load and take manual control.
3. Inform the operator of potential ESS failure and malfunctions.
4. The first alarm event shall be clearly identifiable so that the operator is able to identify the first event in case of a series of alarm events.
5. Provide sufficient diagnostic information that is self-explanatory and in plain English.
6. Error-prone conditions shall be minimized by maintaining operator awareness, providing adequate training and developing standard operating procedures.

Discussion:			
1. Stress, preoccupation, and distraction may reduce the operator's ability to detect faults. 2. In situations where ESS failure would require operator intervention, it is useful for the operator to be warned that he or she will need to take manual control before the ESS fails. Ideally, this warning needs to come in adequate time to allow the operator to adjust to the new task load. There may, however, be cases where it is not possible to provide advance notification of pending failure or where the estimate of time needed for the operator to take control is unknown. 3. It can increase workload for the operator to continually monitor the ESS for failure. Advance knowledge about potential failures can also help the operator prepare to take manual control. 5. In order for the operator to diagnose the ESS, diagnostics information needs to be self-explanatory and in plain language. The diagnostic information must provide the operator with the information they need without requiring the operator to seek additional references, or a help function, to understand the problem and the recommended solution. 6. Errors may arise from data entry errors, monitoring failures, system workarounds, and mode misapplication. Error-prone conditions in ESSs may result from lack of mode awareness, lack of situation awareness, lack of systems awareness, increased heads down time, over-dependence on automation, and interrupted crew coordination. Automation-related errors usually occur in conjunction with other factors such as haste, inattention, fatigue, or distraction.			
Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Assess compliance with relevant standards and usability 'heuristics' concerning the design of alarms and warnings.	☑	☐	☐
Operator Situation Awareness:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of ESS functioning.	☐	☐	☑
• Objective assessment (e.g., probe technique) of the adequacy of the operator's ability to anticipate future ESS failures.	☐	☐	☑
Operator Workload:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's workload.	☐	☐	☑

Operator Trust: • Subjective assessment (i.e., questionnaire) of the adequacy of the operator's trust in the ESS functioning.	☐	☐	☑
Operator Performance: • Objective assessment of the adequacy of the operator's accurate and timely detection of ESS faults and failures.	☐	☐	☑
• Objective assessment of the adequacy of the operator's accurate and timely management of ESS faults and failures.	☐	☐	☑
• Objective assessment of the adequacy of the operator's ability (e.g., speed and error) to resume manual control.	☐	☐	☑
Relationship to Other Guidelines: • 3.3.1.3 Promote ESS Robustness and Resilience to Operator Error			

3.4 Class-Specific Guidelines

3.4.1 Information Management Aids

3.4.1.1	**Optimize Information Presentation and Information Management**	Source: HFDS, 2003; DISA, 1996; DefStan, 1996; Hutchins et al., 1999; AHCI, 1998.

Guideline(s):

1. Information presented to the operator shall accurately reflect system and environment status in a manner so that the operator rapidly recognizes, easily understands, and easily projects system outcomes in relation to system and operator goals.
2. Data changes that occur following Information Management Aid display update shall be temporarily highlighted.
3. Reduce amount of information the operator must evaluate.
4. The Information Management Aid shall provide both information about an object's features and explanatory descriptions which support various decision making processes. For example, a track's features determining its intent and capability (i.e., its "threatiness") shall be displayed and/or easily accessible.
5. The Information Management Aid shall be able to effectively evaluate, integrate and present information to the operator so that an accurate synthesized picture of the situation is achieved.

6. Information presented by the Information Management Aid shall be clear, meaningful, consistent, legible, discriminable, and structured and based on an understanding of the tasks performed by operators.

7. Information shall be unambiguous and meaningful to the operator.

8. When information must be updated quickly, the most important information shall be cued to ensure it will be the first to be processed by the operator. It is important that the cues shall be correct, as there may be significant costs of invalid cueing.

9. Incoming messages shall be queued automatically by the Information Management Aid so they do not disrupt current information handling tasks.

10. Long lists of information, tasks, and so on, shall be stored and prioritized by the ESS to minimize the number of decision alternatives and reduce the visual processing load of human operators.

11. Information Management Aid information shall be automatically reorganized into integrated or non-integrated arrangements depending on the current system status.

12. The Information Management Aid shall provide accurate and reliable information. That is, the correctness of the information in reflecting the reality.

13. The Information Management Aid shall automatically notify the operator of meaningful patterns or events such as when it predicts a future problem.

14. The Information Management Aid shall present information at the level of detail that is appropriate to the immediate task, with no more information than is essential.

15. The Information Management Aid shall avoid repeating information that is already available.

16. The Information Management Aid shall be fully integrated and consistent with the rest of the OMI.

Discussion:

1. Communication will be improved by allowing information to be presented in the most understandable format. Eliminating the need to translate information into a specific format will reduce workload.

2. A primary objective of information automation is to maintain and enhance situation awareness. However, too much information presented simultaneously may become cluttered and make visual search difficult, interfering with status, decision-making, or control. It is important for the operator to be able to easily locate needed information. The operator's ability to detect a signal while monitoring varies inversely with the rate at which neutral background events are repeated. There is also good evidence that the ability to accurately define an event as a signal is improved if the operator has a good understanding of what a non-signal is.

7. Where information coding techniques are used, the meaning associated with codes shall be, as far as possible, based on associations with which the target population can be

expected to be familiar (such as "Red = Danger"). Words, names and abbreviations shall be based on language and terminology used by the target operator population. Data parameters and units shall use formats which are meaningful to the target operators and consistent with the overall task context.

11. Integrated information arrangement allows the operator to assess the overall status of the system. Integrating display components into aggregated arrangements may reduce the attention demands of fault detection. Non-integrated arrangement of components draws operator attention to system errors or other relevant information (i.e., 'pop-out').

12. Accurate and reliable information will increase the operator's trust in the system, support the decision making process and increase the likelihood of an appropriate course of action.

<u>Evaluation Measures and Methodologies:</u>	Inspect	Demonstrate	Experiment
Design:			
• Assess compliance with relevant standards and usability 'heuristics' (e.g., Nielsen, 1994) concerning the presentation of information.	☑	☐	☐
System Performance:			
• Percentage of data objects correctly identified and prioritized.	☐	☑	☐
• Percentage of misses and false positives.	☐	☑	☐
• Age of information.	☐	☑	☐
Operator Performance:			
• Objective assessment of the adequacy of the operator's accurate and timely detection and management of key events	☐	☐	☑
Operator Situation Awareness:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of task-relevant objects in the environment	☐	☐	☑
Operator Workload:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's workload	☐	☐	☑

<u>Relationship to Other Guidelines:</u>

- 3.3.1.1 Employ Operator-Centered Guidelines

3.4.1.2	**Optimize Display of Information**	Source: HFDS, 2003; Hutchins et al., 1999; DefStan, 1996; Zachary and Ryder, 1997.

Guideline(s):

1. Event data shall be combined with a map background when the geographic location of changing events needs to be shown. This might be implemented as an operator-selectable function to avoid unnecessary levels of clutter.

2. Integrated displays shall combine various Information Management Aid information elements into a single representation.

3. Dynamic data that must be monitored by the operator shall be displayed as a graphic format.

4. Automated (i.e., ESS instigated) and non-automated (i.e., operator instigated) cues shall be made equally prominent to enable operators to collect confirming/disconfirming evidence before deciding on appropriate action.

5. Provide operators with displays (e.g., representional aids) that allow them to see directly the information they require rather than infer it from using more cognitively intense levels of data processing.

6. Display elements shall only be integrated if it will enhance status interpretation, decision-making, situation awareness, or other aspects of task performance.

7. Visual representations of data shall be used to (1) present huge amounts of data; (2) show emergent properties of large amounts of data and (3) separate multiple dimensions within a single representation.

8. Graphical displays of information shall be used to reduce the amount of mental processing by allowing operators to spend less time searching for information.

9. Visual representations of information shall be used to represent data relationships.

10. Provide meaningful patterns of information by matching the operator's expertise in the domain (skills and knowledge of the domain).

Discussion:

5. Integrated information arrangement allows the operator to assess the overall status of the system. Integrating display components into aggregated arrangements may reduce the attention demands of fault detection. Non-integrated arrangement of components draws operator attention to system errors or other relevant information (i.e., 'pop-out'). Presenting the information in a format relevant to the state of the system can facilitate the ability of the operator to quickly and easily assess the system status.

7. A large amount of data (e.g., parametric) could be portrayed graphically for rapid assimilation by the operator. For instance, the operator could see, at a glance, a synthesized picture of the track's behaviour. Compared with more complex logical operations, this rather simple perceptual operation allows operators to omit steps that are

otherwise necessary when a task is performed without a visual representation.

8. The graphical presentation of information allows operators to substitute less demanding perceptual operations for more complex logical operations. That is, graphical displays allow decision makers to "see" directly the information they require rather than infer it. For example, determining a change in altitude (and the degree of change) can be immediately apparent when the operator glances at a line graph depicting a track's history. Meanwhile, graphics can help operators save time when searching for needed information when several related dimensions of information are encoded in a single graphical object. Novel graphical displays must be evaluated carefully to ensure that the operator interprets the graphical information in the way intended by the designer.

9. The Information Management Aid can visually represent (1) system relationships, its rule network, and reasoning process; (2) visual associations between related information; and (3) new relationships previously seen as unrelated.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Assess compliance with relevant standards, and usability 'heuristics' concerning the presentation of information.	☑	☐	☐
Operator Situation Awareness:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of task-relevant objects in the environment.	☐	☐	☑
Operator Workload:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's workload.	☐	☐	☑

Relationship to Other Guidelines: None

3.4.2 Decision Making Aids

3.4.2.1	**Ensure Appropriate Implementation**	Source: HFDS, 2003; Hutchins et al., 1999; ACHI, 1998; Zachary and Ryder, 1997; DISA, 1996; Parasuraman and Riley, 1997.

Guideline(s):

1. Decision Making Aids shall be used: for managing system complexity; for assisting operators in coping with information overload; for focusing the operator's attention; for assisting the operator in accomplishing time-consuming activities more quickly; when limited data results in uncertainty; for overcoming human limitations that are associated with uncertainty, the emotional components of decision-making, finite-memory capacity, and systematic and cognitive biases; and, for assisting the operator in allocating

resources, managing detailed information, performing computations, and selecting and deciding among alternatives.

2. The Decision Making Aid shall not be implemented when solutions are obvious; when one alternative clearly dominates all other options; when there is insufficient time to act upon a decision; when the operator is not authorized to make decisions; or for cognitive tasks in which humans excel, including generalization and adapting to novel situations.

3. The Decision Making Aid shall assist, rather than replace, human decision makers by providing data for making judgments rather than commands that the operator must execute.

4. The operator shall be able to configure the Decision Making Aid to provide the kind and level of support he/she requires.

Discussion:

1. The objective of a Decision Making Aid is to increase the speed of analysis of tactical data; allow for more accurate course of action and decision timeliness and agility.

3. Research has shown that experienced decision makers recognize the situation or scenario based on comparison of the features of the current situation with stored memory representations. Once the situation is recognized, solutions or course of action are stimulated by activation of these memory representations.

4. Operators shall be able to determine when and how the Decision Making Aid should be used.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Operator Performance (Decision Making Quality):			
• Subjective assessment (i.e., FASA questionnaire) of the adequacy of the quality of the operator’s situation assessment processes.	☐	☐	☑
• Objective assessment of the adequacy of the timeliness and agility of operator decision making.	☐	☐	☑
• Objective assessment of the adequacy of the consistency of operator decision making.	☐	☐	☑
• Subjective assessment (e.g., peer review) of the adequacy of the justifiability and rationality of operator decision making.	☐	☐	☑
Operator Trust:			
• Subjective assessment (i.e., questionnaire) of the adequacy of Operator trust. Excessive levels of trust may indicate operator complacency (over-trust) and very low levels of trust may	☐	☐	☑

indicate operator scepticism. Operator Workload: • Subjective assessment (i.e., questionnaire) of the adequacy of the operator’s workload.	☐	☐	☑

Relationship to Other Guidelines:

- 3.4.2.2 Support decision making strategies

3.4.2.2	**Support decision making strategies**	Source: HFDS, 2003; Hutchins et al., 1999; ACHI, 1998; Zachary and Ryder, 1997; DISA, 1996; Parasuraman and Riley, 1997.

Guideline(s):

1. The Decision Making Aid shall support decision alternatives.
2. When more than one alternative is available, the Decision Making Aid shall provide alternatives in a recommended prioritization scheme based on mission and task analysis.
3. When the information used by a Decision Making Aid is derived or processed, the data from which it is derived shall be either visible or accessible for verification.
4. The Decision Making Aid shall be capable of planning a strategy to address a problem or guide a complex process.
5. Develop models of decision making strategies specific to the domain and the mission. From the decision making model, the type of information to display and how to display it will become evident.
6. The Decision Making Aid shall keep the number of response options to a manageable number.
7. The support provided by the Decision Making Aid shall be consistent with operator cognitive strategies and expectations (mental models). A mental model is an individual’s understanding of the processes underlying system operation.
8. The Decision Making Aid shall be able to predict future data based on historical data and current conditions.
9. The Decision Making Aid shall minimize queries by the operators for information.
10. The Decision Making Aid shall be tailored to the expertise and skill of the decision maker and the support for one level of expertise shall not interfere with the support for operators with different levels of expertise.

Discussion:

1. Arguments leading to system results and alternative solutions shall be displayed so that the operator is able to comprehend and evaluate computer-generated proposals and

formulate a well-informed decision.

3. Data that are not critical for an operation can be made available only upon request.

4. Ensure that the Decision Making Aid guides the operator through the process, providing automated guidance on how to define and analyze a problem and formulate a decision.

6. The number of options that the operator must consider is expected to decrease when a Decision Making Aid is used. Reducing the response options focuses the operator's attention onto the most viable options. However, presenting too few options might promote 'cognitive tunnel vision', which should be avoided.

10. For instance, novices to the domain may rely on a rule-based interface (i.e., analytical) to aid in their decision process while experts may be more responsive to mental imaging techniques (e.g., Recognition-Primed Decision or feature matching). Novices typically have good knowledge of the domain (i.e., C^2 processes) but it is composed largely of facts and basis concepts. Decision making strategies generally involve analyzing individual multiple variables and applying general, domain-independent problem solving methods (e.g., trial and error). As the operator becomes more adept, the consolidated knowledge and problem solving approaches support the use of seemingly more recognition/case-based approaches. Such an operator has developed a complex set of integrated declarative (the "what") and procedural (the "how to") knowledge both about the domain and about the decision tasks to be performed in the domain. This rich mental model of the domain allows the operator to apply elaborated domain-based solutions. The Decision Making Aid shall be designed to support the expert decision maker to recognize the case into which a specific decision situation fits. The expert decision maker can then retrieve the appropriate solution strategy and directly apply it with little or no intermediate analysis or reasoning.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Operator Decision Making Quality:			
• Subjective assessment (i.e., FASA questionnaire) of the adequacy of the quality of the operator's situation assessment processes.	☐	☐	☑
• Objective assessment of the adequacy of the timeliness and agility of operator decision making.	☐	☐	☑
• Objective assessment of the adequacy of the consistency of operator decision making.	☐	☐	☑
• Subjective assessment (e.g., peer review) of the adequacy of the justifiability and rationality of operator decision making.	☐	☐	☑
Operator Situation Awareness:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of the reasoning behind recommendations from the Decision Making Aid	☐	☐	☑

(i.e., system transparency). Operator Workload: • Subjective assessment (i.e., questionnaire) of the adequacy of the operator's workload. Operator Trust: • Subjective assessment (i.e., questionnaire) of the adequacy of operator trust. Excessive levels of trust may indicate operator complacency (over-trust) and very low levels of trust may indicate operator scepticism.	 ☐ ☐	 ☐ ☐	 ☑ ☑
Relationship to Other Guidelines: • 3.4.2.1 Ensure Appropriate Implementation			

3.4.2.3	**Keep Operators in Control**	Source: HFDS, 2003; DefStan, 1996; MS1472F; Parasuraman and Riley, 1997; Sheridan, 2000.

Guideline(s):

1. Operators shall be able to determine when and how the Decision Making Aid shall be used.
2. The Decision Making Aid shall not be able to veto operator actions leaving the operator without means to override or violate rules that govern the Decision Making Aid unless there is not enough time for the operator to make a decision.
3. The operator shall be able to initiate (i.e., over-ride) the automation of tasks even when a task has been designated to be Decision Making Aid-initiated.
4. The Decision Making Aid shall assist, rather than replace, human decision makers by providing data for making judgments rather than commands that the operator must execute.
5. The Decision Making Aid shall allow the operator to receive direct assistance in planning how to carry out the intended task.
6. The Decision Making Aid shall accept direction from the operators on which problem solving strategy to employ when alternative strategies are available.
7. Automated tasks or functions shall not be able to jeopardize safety or make a difficult situation worse.
8. When an operator might need to operate in out-of-tolerance conditions, then a deliberate overriding action shall be possible.

Discussion:			
1. Operator acceptance of a Decision Making Aid centres on whether the operator feels in control of the system. 8. There may be cases, particularly in an emergency situation, when the operator needs to operate in out-of-tolerance conditions.			
Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Operator Trust			
• Subjective assessment (i.e., questionnaire) of the adequacy of operator trust. Excessive levels of trust may indicate operator complacency (over-trust) and very low levels of trust may indicate operator scepticism.	☐	☐	☑
Operator Situation Awareness			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of task-relevant objects in the environment.	☐	☐	☑
Operator Workload:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's workload.	☐	☐	☑
Relationship to Other Guidelines: • 3.3.5 Support Identification and Management of ESS Faults and Failures • 3.4.3.1 Keep Operators 'In-the-Loop'			

3.4.2.4	**Maximize Operator Situation Awareness by Increasing System Transparency**	Source: HFDS, 2003; Zachary and Ryder, 1997; Hutchins et al., 1997; DefStan, 1996; Endsley, 1996.
Guideline(s): 1. Processed data shall be accessible. 2. Promote knowledge about the intent of the Decision Making Aid to the Operator. 3. The Decision Making Aid shall estimate and indicate the certainty of analysis and provide the rationale for the estimate. 4. The Decision Making Aid shall give the operator access to procedural information used by the aid. 5. When the Decision Making Aid provides explanations to the operator, it shall supply a		

short explanation initially, with the ability to make available more detail at the operator's request, including access to process information or an explanation for the rules, knowledge-basis, and solutions used by the decision aid.

6. When the Decision Making Aid provides explanations to the operator, the explanation shall use terms familiar to the operator and maintain consistency with the immediate task.

7. The Decision Making Aid shall alert the operator to changes in the status of important system information such as when critical information becomes available during decision aid utilization.

Discussion:

1. Where displays contain potentially large amounts of information, consideration shall be given to providing operators with facilities to manage the amount and types of information displayed at any one time. This can be achieved by applying filters and artificial intelligence (e.g., algorithms) based on the operator role to help process the data.

2. Monitoring of the Decision Making Aid by the operator and the operator by the system can only be effective if each knows what the other one is trying to accomplish (i.e., intent). This might be achieved by displaying the current goals of the Decision Making Operator (as well as progress made towards those goals).

3. Research pertaining to the representation of system certainty (or uncertainty) to the operator is immature. Any attempt to represent system certainty (or uncertainty) to the operator must be thoroughly evaluated.

4. Procedural information is information about the rules or algorithms used by the Decision Making Aid. Knowledge of procedural information fosters operator acceptance of the aid because the operator is able to understand how the aid functions. As the operator becomes more familiar with a given situation, he or she requires less procedural information.

5. Process information is the information about how the Decision Making Aid accomplishes a task. This information is required by operators to decide whether to use the aid in unfamiliar situations and for identifying the nature and extent of malfunctions.

7. Critical information in this standard refers to information that may have a significant impact on task completion.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Operator Situation Awareness:			
• Subjective assessment (i.e., FASA questionnaire) of the adequacy of the quality of the operator's situation assessment processes	☐	☐	☑
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of task-relevant objects in the environment	☐	☐	☑

• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's Situation Awareness of the reasoning behind recommendations from the Decision Making Aid (i.e., system transparency).	☐	☐	☑
Operator Workload:			
• Subjective assessment (i.e., questionnaire) of the adequacy of the operator's workload.	☐	☐	☑
Operator Trust			
• Subjective assessment (i.e., questionnaire) of the adequacy of operator trust. Excessive levels of trust may indicate operator complacency (over-trust) and very low levels of trust may indicate operator scepticism.	☐	☐	☑
Relationship to Other Guidelines: • 3.3.1.4 Support Operator Monitoring of ESS Functioning • 3.3.4 Provide System Response and Feedback			

3.4.3 Control and Action Aids

3.4.3.1	**Keep Operators 'In-the-Loop'**	Source: HFDS, 2003; Sheridan, 2000; MS1472F; DefStan, 1996; Endsley and Kaber, 1999.
Guideline(s): 1. When tasks are automated, the tasks shall be easily understood by operators and matched to the operator's mental model of the task. 2. The Control and Action Aid shall provide the operator with an appropriate range of control options that are flexible enough to accommodate the full range of operating conditions for which it was certified. 3. To promote sufficient levels of operator situation awareness of the Control and Action Aid, the operator shall be given immediate feedback to command and control orders. 4. Override and backup control alternatives shall be available for automated tasks that are critical to the integrity of the system or when lives depend on the system. 5. The operator shall be able to initiate and control the direction and pace of the tasks and/or functions of the Control and Action Aid until the point at which operator goals have been met, 6. Information for backup or override capability shall be readily accessible. 7. The Control and Action Aid shall be designed so that operators are involved in active		

control and monitoring rather than just passive monitors. 8. Allow reversal of operator actions (e.g. ‘undo’ or ‘cancel’ function) and give clear indications how reversal can be achieved.			
<u>Discussion:</u> 2. Highly flexible Control and Action Aids can be useful when the operator knows how to implement the various options across a wide spectrum of operational situations. However, the multiple options that are associated with highly flexible systems also require additional cognitive resources in order for the operator to remember which mode is active. 7. An active role will decrease the likelihood of complacency and lower vigilance and may increase situation awareness. 8. In order to facilitate the operator’s perception of being in control (as opposed to the perception of the Control and Action Aid being in control of the operator), the Control and Action Aid shall allow the operator an easy exit out of as many interactions as possible. For example, by providing a cancel button, and undo and redo operations.			
<u>Evaluation Measures and Methodologies:</u>	Inspect	Demonstrate	Experiment
Operator Situation Awareness: • Subjective assessment (i.e., questionnaire) of the adequacy of the operator’s Situation Awareness of the reasoning behind the actions of the Control and Action Aid (i.e., system transparency).	☐	☐	☑
Operator Trust: • Subjective assessment (i.e., questionnaire) of the adequacy of operator trust. Excessive levels of trust may indicate operator complacency (over-trust) and very low levels of trust may indicate operator scepticism.	☐	☐	☑
Operator Workload: • Subjective assessment (i.e., questionnaire) of the adequacy of the operator’s workload.	☐	☐	☑
<u>Relationship to Other Guidelines:</u> • 3.3.1.4 Support Operator Monitoring of ESS Functioning • 3.3.4 Provide System Response and Feedback • 3.4.2.4 Maximize Operator Situation Awareness by Increasing System Transparency			

3.5 Design and Evaluation

3.5.1	**Adopt Operator-Centered Design Principles**[2]	Source: HFDS, 2003; DefStan, 1996; AHCI, 1998; DISA, 1996; Zachary and Ryder, 1997; MS1472F.

Guideline(s):

1. The design of an ESS shall begin by choosing the human-centered criteria (goals) of the system and then defining the functions that the system will perform.

2. Standard operating procedures and company policies shall guide system designers in the appropriate allocation of a task to the operator or the ESS, although the operator shall be ultimately responsible to make the decision to use or not use the automation.

3. A substantial proportion of the operators shall be involved in the design of the ESS.

4. The ESS shall be based on operator population characteristics (cognitive and heuristic biases, skills, experience, training) and cognitive processes (mental representation and decision strategy) of the operator.

5. The unique contextual and environmental considerations shall be incorporated into the design of the ESS to support decision making.

6. When a new ESS technology is introduced, the designers shall consider the possibility of negative effects on team coordination.

7. The overall impact of an ESS shall be thoroughly examined before implementation to ensure that changes do not result in additional complexities, loss of Situation Awareness, or possibilities for error.

8. The ESS shall keep an up-to-date record of where the operator currently is within a sequence of tasks or activities.

9. Organize the functionality of the ESS in line with the operator's tasks.

10. ESS-related information shall be structured according to the operator's task.

Discussion:

1. An operator-centered design process is a highly structured, comprehensive product development methodology driven by (1) clearly specified, task-oriented objectives and (2) recognition of operator needs, limitations and preferences. Information collected using this analysis is scientifically applied in the design, testing and implementation of an ESS. Defining the goals and functions of an ESS may require the use of a mission, function and task analysis.

2. Input from the operator is essential in defining information requirements. To increase the likelihood that the new system will "fit" most operators and the constraints of their tasks, a representative number of operators shall be involved to provide advice and feedback in the development of the system. Not only shall this help with system development, but it shall

[2] These guidelines apply to the whole system (and not just the ESS).

also give a reasonable number of operators a feeling of "ownership" which they can transmit to their colleagues, thereby helping to facilitate the development of trust.

6. Automation of tasks may deplete team interaction and cooperation unless all parties are provided with information that allows them to be actively involved in the task. Task automation can cause physical difficulty in seeing what the other team member is doing, reduce the ability to cross monitor, change traditional roles and responsibilities, and change the manner in which team members attempt to help one another.

8. This allows the operator to resume tasks smoothly and efficiently after being interrupted.

9. Information objects and operations shall be accessible in a sequence that matches the way operators will most effectively and productively do things with minimal error.

10. Essential information that is regularly needed, cross-checked, or time-critical should be prominently displayed. Less essential information can be less prominently displayed, or minimized, pending examination at another time.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Assess design methodology is compliant with MIL-HDBK-46855A (Human Engineering Program Process and Procedures).	☑	☐	☐
• Assess overall OMI design is compliant with COMDAT OMI Style Guide (and other relevant Human Factors standards) and usability 'heuristics'.	☑	☐	☐
Operator Acceptance:			
• Subjective assessment of the adequacy of system usability and utility by Human Factors professional using 'walk-through' or heuristic analysis.	☐	☐	☑
• Questionnaire-based assessments of the adequacy of operator's perceptions of system usability and utility	☐	☐	☑

Relationship to Other Guidelines:

- 3.3.1.1 Employ Operator-Centered Principles
- 3.3.2 Employ Operator-centered OMI Design

3.5.2	**Adopt Operator-Centered Evaluation Principles**	Source: HFDS, 2003; DefStan, 1996.

Guideline(s):

1. Possible interactions with other tools, system functions, and operator tasks shall be evaluated when a new ESS is designed.

2. New ESS components shall be tested with the complete system, including other system components of the ESS, to ensure they function together as an effective whole.

3. The ESS shall be tested under normal modes of operation and under failure modes of operation.

4. Contextually valid human-in-the-loop experiments and simulations shall be conducted to validate and refine the ESS design.

5. Evaluations of the usability of the system shall be carried out at all phases of the system development.

6. The ESS shall be tested in a realistic operational environment using tasks and operators representative of the final system.

Discussion:

5. These evaluations shall be used both to assist in deciding between alternative design options, and to support validation that the design satisfies the system's operability requirements.

6. The tasks shall provide reasonable coverage of the most important parts of the system. The test tasks can be designed based on a task analysis or on a product identity statement listing the intended uses for the system.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design • Assess evaluation methodology is compliant with MIL-HDBK-46855A (Human Engineering Program Process and Procedures)	☑	☐	☐

Relationship to Other Guidelines: None

3.6 Training and Implementation

3.6.1	**Manage Introduction of the ESS**	Source: HFDS, 2003; DefStan 1996; Parasuraman and Riley, 1997; Zachary and Ryder, 1997; DISA, 1996.

Guideline(s):

1. An ESS shall be introduced with advanced briefing and subsequent training.

2. Before the ESS is introduced, operators shall be informed of associated changes and increases in the work effort, as well as the benefits associated with the ESS.

3. Operators shall be trained to acquire an adequate understanding (mental model) of how the ESS works in order to use it effectively.

4. Training programs shall stress human-system interaction skills and cognitive/problem solving skills rather than psychomotor skills.

5. When the ESS requires different kinds of cognitive processing, ways of thinking, and discarding of traditional methods and skills, then training shall be designed to address problems related to these changes.

6. Operators shall be trained on what constitutes the normal ESS output so that the operator can easily determine whether the system is functioning properly.

Discussion:

1. The introduction of the ESS may introduce changes in traditional roles and responsibilities, a redistribution of authority for tasks or changes to the nature of the cognitive demands imposed on the human operator.

2. The roles and responsibilities of the operators, cognitive demands, and operational procedures may change as a result of introducing automation.

3. Operators must possess accurate mental models of the system in order to use it effectively, comprehend current situations, plan their actions, predict future system states and diagnose system failures.

4. Problems in automation may not be inherent in the technology itself. Problems can arise due to limitations in the integration of the operator and automation.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Training plan includes Training Needs Analysis (TNA).	☑	☐	☐
• Training plan compliant with MIL-HDBK-46855A	☑	☐	☐

guidance for training (i.e., minimize training requirements).			
• Training plan includes regular training evaluations.	☑	☐	☐
• Subjective assessment of adequacy of embedded training system (if applicable).	☑	☐	☐
Operator Acceptance:			
• Subjective assessment (i.e., questionnaire) of the adequacy of operator's acceptance of ESS.	☐	☐	☑
• Subjective assessment (i.e., questionnaire) of the adequacy of operator's perception of ESS usefulness.	☐	☐	☑

Relationship to Other Guidelines:

- 3.6.2 Train to Overcome 'Automation Biases'
- 3.6.3 Train to Overcome ESS Failures
- 3.6.4 Promote Operator Acceptance and Trust in ESSs

3.6.2	**Train to Overcome 'Automation Biases'**	Source: HFDS, 2003; DISA, 1996; Parasuraman and Riley, 1997.

Guideline(s):

1. Operators shall be trained to recognize inappropriate uses of an ESS including automation bias (the use of automation in a heuristic manner as opposed to actively seeking and processing information).

2. Operators shall be trained to recognize and understand the conditions under which the system may be unreliable, and to learn the conditions where it performs well (when or when not to question the automation).

3. Operators shall be trained not to become overly reliant on automation.

Discussion:

1. There are different categories of inappropriate automation use, including automation bias, ignoring or turning off the automation, and improper implementation of automation. Operators may rely on decision aids in a heuristic manner (referred to as automation bias). Using heuristics is to apply simple decision-making rules to make inferences or to draw conclusions simply and quickly. Heuristics are useful principles having wide application, but may not be strictly accurate. Usually a heuristic strategy is optimal, however, under certain conditions heuristics will be inappropriate and errors or misuse may occur. Automation bias leads to errors of omission (failure to notice system anomalies when automation fails) and errors of commission (acceptance of automated decisions without cross-checking or in presence of contradictory information). Training will help prevent

automation bias and help the operator learn to examine multiple sources of information before making a decision. Early training on automation bias may reduce commission errors for operators new to automation, but may be less likely to reduce omission errors or errors made by expert operators. Inappropriate use of automation may be influenced by various individual factors such as self-confidence in completing the task, trust in the automation, differential effects of fatigue, and how all of these factors combined weigh into the decision making process. Inappropriate use of automation can be due to misuse (automation bias, complacency), disuse (ignoring or turning off automation) or abuse (improper implementation of automation).The roles and responsibilities of the operators, cognitive demands, and operational procedures may change as a result of introducing automation.

2. Operators must learn not to categorically accept the recommendation of a decision aid. Understanding the automation's weaknesses allows operators to better judge how much they shall trust the automation without becoming overconfident in its performance. This recognition process may impose an additional workload on the operator.

3. When operators rely on automation too much they become susceptible to automation-induced complacency. Monitoring failures are likely to occur when operators become overly reliant on automation.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Training plan includes Training Needs Analysis (TNA)	☑	☐	☐
Operator Trust:			
• Subjective assessment (i.e., questionnaire) of the adequacy of operator trust. Excessive levels of trust may indicate operator complacency (over-trust) and very low levels of trust may indicate operator scepticism.	☐	☐	☑
Operator Situation Awareness:			
• Subjective assessment (i.e., FASA questionnaire) of the adequacy of the quality of the operator's situation assessment processes (this questionnaire includes items relevant to automation bias).	☐	☐	☑

Relationship to Other Guidelines:

- 3.6.1 Manage Introduction of the ESS
- 3.6.3 Train to Overcome ESS Failures
- 3.6.4 Promote Operator Acceptance and Trust in ESSs

3.6.3	**Train to Overcome ESS Failures**	Source: HFDS, 2003; AHCI, 1998; Endsley, 1996; Parasuraman and Riley, 1997.

Guideline(s):

1. Operators shall be trained on risk assessment and actions needed for risk reduction.
2. Operators shall be trained on transitioning from the ESS to manual operations.
3. Operators shall be trained to ensure proper understanding of the ESS's processes.

Discussion:

2. If the ESS was to fail, operators need to be skilled at both recognizing the failure and taking manual control.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Training plan includes Training Needs Analysis (TNA)	☑	☐	☐
Operator Performance:			
• Objective assessment of the adequacy of the operator's ability (e.g., speed and error) to resume manual control.	☐	☐	☑
• Objective assessment of the adequacy of the operator's ability (e.g., speed and error) to detect and manage ESS failures.	☐	☐	☑

Relationship to Other Guidelines:

- 3.6.1 Manage Introduction of the ESS
- 3.6.2 Train to Overcome 'Automation Biases'
- 3.6.4 Promote Operator Acceptance and Trust in ESSs

3.6.4	**Promote Operator Acceptance and Trust in ESSs**	Source: HFDS, 2003; DefStan, 1996; MS1472F; Parasuraman and Riley, 1997.

Guideline(s):

1. Training shall be provided to enable the operator to calibrate their trust in the ESS.
2. Changes in cognitive processing, ways of thinking, and methods and skills used for the ESS shall be minimized.

3. To promote operator acceptance, operators shall be trained to ensure proper understanding of the system's processes.

Discussion:

1. Training will allow the operator to develop an adequate model of how reliable or unreliable the ESS is under specific conditions.

2. An ESS that requires different kinds of cognitive processing, ways of thinking, and discarding of traditional methods and skills may cause the system to be both less efficient and less acceptable to the operators. This could include automatic conversion of data into a usable format.

3. The better the operator understands the ESS, the more likely the operator is to trust the ESS appropriately. Designers need to alter the false belief that ESSs are perfect and ensure that the operators understand when the system is likely to become unreliable.

Evaluation Measures and Methodologies:	Inspect	Demonstrate	Experiment
Design:			
• Training plan includes Training Needs Analysis (TNA)	☑	☐	☐
• Training plan includes regular training evaluations	☑	☐	☐
Operator Trust:			
• Subjective assessment (i.e., questionnaire) of the adequacy of operator trust. Excessive levels of trust may indicate operator complacency (over-trust) and very low levels of trust may indicate operator scepticism.	☐	☐	☑
Operator Acceptance:			
• Subjective assessment (i.e., questionnaire) of the adequacy of operator's acceptance of ESS.	☐	☐	☑
• Subjective assessment (i.e., questionnaire) of the adequacy of operator's perception of ESS usefulness.	☐	☐	☑

Relationship to Other Guidelines:

- 3.6.1 Manage Introduction of the ESS
- 3.6.2 Train to Overcome 'Automation Biases'
- 3.6.3 Train to Overcome ESS Failures

4 Conclusions

4.1 Summary

The development of standards and guidelines presented in this document are intended specifically to:

- Enhance the usability of the ESS technologies developed within the INCOMMANDS project; and,
- To minimize the probability (and impact) of operator error under the stressful conditions of the battlefield environment.

In general, standards and guidelines (which include the present document) specify the ‘look’ and ‘behaviour’ of the operator’s interaction with the decision aid OMI. As with all guidelines, those that are optimal for one situation may not be suitable for another situation. As a consequence, design trade-offs might occur that contradict one particular standard in favour of supporting another. In these cases, it is important that each design trade-off is recorded and the consequences for overall system performance are evaluated in consultation with a person experienced in psychometric-based evaluations.

4.2 The Way Ahead

The present document represents a significant step towards a comprehensive Human Factors Design and Evaluation Guide to support and inform the design of OMIs for decision aids, and related technologies, used within the context of naval C^2 applications. In addition, the guide will include general guidance regarding how to evaluate compliance with the guidelines. The following sections discuss a number of possible ways forward for the OMI design guidelines and the evaluation criteria.

4.2.1 OMI Design Guidelines

It is critical that developing OMIs be subject to continual review to both confirm compliance (using the evaluation criteria outlined in this document) with the design guidance provided in this document, and identify usability problems in the OMI. As successful solutions are developed, they should be captured as design specifications and added to the guidance provided in this document. It is therefore imperative that the document is iterated in line with the experimental studies within, and outside of, the INCOMMANDS project.

4.2.2 Evaluation Measures and Methodologies

The vast majority of evaluation measures described within this document require some form of human-in-the-loop experimentation. This is due to a combination of the imprecision of the constructs that need to be measured (e.g., Situation Awareness, workload and trust), the imprecision of the measurement tools used to measure these constructs, and the imprecision of the guidelines themselves. For example, some aspects of the design of OMIs, such as font size, colour coding and menu structures, can be specified in detail and evaluated using solely inspection methods. However, most of the guidelines within this document are not as clearly specified and therefore need time-consuming and expensive experimentation methods to determine compliance. It is therefore imperative that any lessons learnt from one OMI development project should be shared with the wider community. For example, following experimental studies to evaluate compliance of a candidate OMI to these guidelines, the results of these studies should be captured in the form of more detailed design specifications and evaluation methods.

4.2.3 Integration with COMDAT OMI Style Guide

The next stage for this work is to integrate the guidance within this document with the guidance provide in the existing COMDAT OMI Style Guide to form a final document, the INCOMMANDS Human Factors Design and Evaluation Guide. This comprehensive guide will cover both the design of the OMI and decision aid guidance, used within the context of naval C^2 applications. Some preliminary recommendations are suggested below for integrating the two documents:

- *Structure of the INCOMMANDS Human Factors Design and Evaluation Guide*. The guidance within this document comprises guidelines relevant to aiding and supporting operator decision making as well as promoting high levels of operator trust and acceptance of the system. The COMDAT OMI Style Guide on the other hand provides guidance to create a common look and feel and of basic principles of OMI usability. While both style guides provide OMI design guidance that is complimentary to each other, the focus of each style guide is different and requires that these guidelines are treated individually. It is recommended that the INCOMMANDS Human Factors Design and Evaluation Guide be comprised of two main sections; one section should address guidelines specific to supporting decision making while the other section should provides concrete OMI design guidance.
- *Ensure consistency among the guidelines provided in this document with those provided in the COMDAT Style Guide.* Suggestions for additional OMI guidance and/or removal or modifications of existing guidance in this document and from the COMDAT Style Guide shall be provided to ensure that all guidelines are consistent.
- *Cross-referencing of guidelines.* Where appropriate, the guidelines from the COMDAT Style Guide should refer to the guidelines found within this document for supporting justification of OMI design guidance related to decision aiding. Similarly, the guidelines from this document should refer to concrete OMI design guidelines in the COMDAT Style Guide for guidance on implementing decision aiding principles.
- *Structure the format of the COMDAT Style Guide to emulate the guidelines format within this document.* The guidelines within COMDAT Style Guide should be structured to impose a consistent and logical format consistent with the format of the guidelines in this report. Each and every COMDAT guideline would be composed of a summary section followed by a list of guidelines relevant to the topic. To ensure compliance with the COMDAT Style Guide, the evaluation measures outlined in the present document, in terms of metrics and tools, would be used for the evaluation of a proposed OMI.

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6 Acronyms

AWW	Above Water Warfare
BMC4I	Battle Management Command, Control, Communications, Computers and Intelligence
C^2	Command and Control
CDSC	Command Decision Support Concept
CFMWC	Canadian Forces Maritime Warfare Centre
COMDAT	Command Decision Aiding Technology
CONOPS	Concept of Operations
CPF	Canadian Patrol Frigate
DEP	Demonstration and Experimental Plan
DISA	Defense Information Systems Agency
DND	Department of National Defence
DoD	Department of Defence
DSS	Decision Support System
ESS	Electronic Support System
FAA	Federal Aviation Administration
FASA	Factors Affecting Situation Awareness
HFDG	Human Factors Design Guide
HFDS	Human Factors Design Standard
HFEPP	Human Factors Engineering Program Plan
HMCCS	Halifax Modernized Command and Control System
INCOMMANDS	Innovative Naval COMbat MANagement Decision Support
KBS	Knowledge-Based System
LoL	Levels of Automation
MFTA	Mission, Function and Task Analysis
NASA-TLX	National Aeronautics and Space Administration-Task Load Index
OODA	Observe Orient Decide Act
OMI	Operator Machine Interface
ORO	Operations Room Officer
PEOU	Perceived Ease-of-Use
PU	Perceived Usefulness
SA	Situation Awareness
SAGAT	Situation Awareness Global Assessment Technique
SART	Situation Awareness Rating Technique
SWC	Sensor Weapons Controller
TADMUS	Tactical Decision Making Under Stress
TAM	Technology Acceptance Model
TDP	Technology Demonstration Program
TEWA	Threat Evaluation and Weapons Assignment
UCD	User-Centered Design

Annex A: Basic OMI Design Requirements

The following section describes general usability heuristics, or ‘rules of thumb’, that have been developed and are widely accepted within the human factors industry (e.g., Nielsen, 1994). The following heuristics are considered to be basic requirements for complex operator interfaces and, as such, can be used as over-arching guidelines throughout the development of the INCOMMANDS Human Factors Design and Evaluation Guide:

- *Visibility of system status*. The system shall always keep operators informed about what is going on, through appropriate feedback, within reason;
- *Match between system and the real world.* The system shall speak the operators’ language, with words, phrases and concepts familiar to the operator, rather than system-oriented terms. Real-world conventions shall be followed to make information appear in a natural and logical order;
- *Operator control and freedom.* Operators often choose system functions by mistake and will need a clearly marked “emergency exit” to leave the unwanted state without having to go through an extended dialogue. Undo and redo functionality shall be supported where practical;
- *Error prevention.* Careful design shall prevent problems from occurring in the first place; if errors do occur, appropriate alarms and alerts shall be presented to the operator;
- *Recognition rather than recall.* Objects, actions, and options shall be visible to the operator at all times. The operator shall not have to remember information from one part of the dialogue to another. Instructions for use of the system shall be visible or easily retrievable whenever appropriate;
- *Flexibility and efficiency of use*. Accelerators (e.g., hot-keys), which are unseen by the novice operator, shall be used to speed up the interaction for the expert operator. In this way, the system can cater to both inexperienced and experienced operators. Operators shall also be allowed to tailor how they perform frequent tasks (e.g., re-configure windows);
- *Help operators recognize, diagnose, and recover from errors.* Error messages shall be expressed in plain language, precisely indicate the problem, and constructively suggest a solution;
- *Help and documentation.* Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information shall be easy to search, focused on the operator’s task, list concrete steps to be carried out, and not be too large; and,
- *Consistency and standards.* Operators shall not have to wonder whether different words, situations, or actions mean the same thing. Platform conventions shall be followed where practical. C^2 relies on data being presented in a manner that contributes to the operators’ knowledge of the tactical situation; the ability to access information and to convert it to knowledge is enhanced if the OMI is consistent. Consistency in the OMI design permits the operators to devote their attention to the information supplied by the system rather than to the system itself. If the OMI is consistent throughout the application, and is

consistent with other computer experiences, then the operators do not need to devote attention to details of operating the software controls and displays. Instead, cognitive processing is focused on the tactical information.

One of the major goals of the INCOMMANDS Human Factors Design and Evaluation Guide is to enforce consistency. To achieve this goal, there must be consistency within the OMI and between OMIs. In addition, consistency is not just a question of interface design but includes the consideration of tasks and functionality structure of the system that match the tasks and decision making processes of the operator. Each instance of inconsistency is likely to produce unnecessary cognitive processing and affect the cognitive processing available to the decision maker for the actual combat tasks. The INCOMMANDS OMI therefore shall be designed to be consistent; appearing, behaving and responding the same throughout. The following is a list of the different types of consistency that shall be considered:

- *Consistency with the current Canadian Patrol Frigate (CPF) CCS system*.
- *Consistency with existing military OMI style guides*. In particular, the COMDAT V2, AHCI (1998), DISA (1996), and MIL-STD 1472F.
- *Visual consistency (general OMI layout "look and feel").* The same information shall be presented in the same location on all screens and dialogue boxes and it shall be formatted in the same way to facilitate recognition. Menus shall be presented in a consistent format throughout the system and shall be readily available at all times.
- *Consistency with operator expectations.* Display-control relationships must be compatible with the operator's expectations, and require minimum processing to extrapolate the information from the system.
- *Consistency with the decision maker's mental representation.* The problem representation within the decision aid shall reflect the problem representation, cognitive strategies and expectations and work practices of the decision maker.
- *Consistent language/terminology.* Small changes in the language lead to errors and confusion. Operators assume that different terms reflect differences in the software. For example, the term "Close" is expected to result in a different action than "Exit" so these shall not be used to label the same action. Conversely, if more than one term is used to convey the same concept, then the operator must determine if two different terms reflect the same software activity or a different software activity. For example, an application may incorrectly use three notations: "Stop", "Cease", and "End" each to mean that the processing will not be continued (e.g., identical terminology shall be used in prompts, menus, and help screens).
- *Consistent symbols and icons.* Using more than one icon design to represent instances of a single type of control will lead to errors and confusion. For example, using a door icon and an "X" symbol both to indicate "Close" in an application will lead the operator to assume that the "X" and "Close" operate differently.
- *Feedback consistency.* The interface shall have a reliable and consistent method of system response across applications. Transactions made by the operator shall produce a consistent perceptual response whether it is in visual, tactile, or auditory form.

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The INCOMMANDS TDP seeks to research, demonstrate and evaluate new command decision support concepts for the HALIFAX Class frigate's command and control (C2) system, with the objective of improving team battlespace awareness, and increasing decision speed and accuracy. The aim of this document is to support the design and development of Operator Machine Interface (OMI) concepts developed as part of the INCOMMANDS TDP by providing a structured and comprehensive set of design guidelines which address decision aiding concepts specifically. The guidance within this document will be integrated within a final document, the INCOMMANDS Human Factors Design and Evaluation Guide, which will cover both OMI and decision aid guidance.

Le PDT INCOMMANDS cherche à mettre au point, à expérimenter et à évaluer les nouveaux concepts de soutien à la décision du commandement (SDC) pour le système de commandement et de contrôle (C2) de la frégate de la classe HALIFAX dans le but de sensibiliser davantage les équipes à ce qui se passe sur le terrain et de permettre une prise de décision plus rapide et éclairée. Le présent document vise à appuyer la conception et l'élaboration des concepts d'interface opérateur-machine (IOM) élaborés dans le cadre du PDT INCOMMANDS en fournissant un ensemble structuré et complet de lignes directrices relatives à la conception traitant particulièrement des concepts d'aide à la décision. Les directives contenues dans le présent document seront intégrées dans un document final, le Guide de conception et d'évaluation tenant compte des facteurs humains - INCOMMANDS, qui couvrira les directives relatives à l'IOM et à l'aide à la décision.

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

INCOMMANDS; decision support; operator-machine interface; guidelines; measures of performance; methodology; design guidance; Navy; command and control